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Leachate Monitoring in Naturally Saline Groundwater Chesapeake Landfill Chesapeake Virginia

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LEACHATE MONITORING IN NATURALLY SALINE GROUNDWATER, CHESAPEAKE LANDFILL, CHESAPEAKE, VIRGINIA

by

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B.A. May 1981, Old Dominion University

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MASTER OF SCIENCE

GEOLOGY

OLD DOMINION UNIVERSITY
December, 1985

Approved by:

Dr. J. H. Rule

Dennis A. Darby

G. Richard Whittecar

ABSTRACT

LEACHATE MONITORING IN NATURALLY SALINE GROUNDWATER, CHESAPEAKE LANDFILL, CHESAPEAKE, VIRGINIA

T. Britt McMillan
Old Dominion University, 1985
Director: Dr. J. H. Rule

Groundwater chemistry around the Chesapeake municipal landfill was monitored over a one year period. Ten sample sites as well as two surface water sites were used to monitor water quality. Two wells, one at 3 m and the other at 10 m were located at each site. Surface water samples were taken from the Elizabeth River, north of the landfill, and a tidal channel, west of the landfill. Seven groundwater sites were downgradient of the landfill and three sites were upgradient (control sites).

The landfill overlies a tidal marsh, approximately 100 m south of the intracoastal waterway (Elizabeth River). Dredge spoils overlying a marsh clay-muck separate the landfill from the waterway to the north. To the east and south is a sandy loam soil and to the west is a tidal marsh. The underlying aquifer is fairly homogeneous vertically and horizontally, consisting of medium to fine, moderately sorted sand which is strongly fine-skewed leptokurtic.

Groundwater and surface water samples were monitored for pH, Eh, temperature, conductivity, salinity, hardness, NO_3, NO_2, TKN, TPO_4, OPO_4, SO_4, Cl, Na, K, Ca, Mg, Fe, Mn, and Zn. ANOVA and factor analysis aided in identifying sources of variance in the parameters measured. Conductivity, salinity, hardness, sulfate, sodium, chloride, and magnesium, though present in high concentrations in the leachate, were most indicative of the surface water. Potassium, total and orthophosphate, and TKN best characterized the leachate.

Tidal fluctuation had no observable impact on the groundwater chemistry, though there did appear to be some seasonal influence on the leachate concentration.

ACKNOWLEDGEMENTS

I would like to express my appreciation to all the people who gave guidance and assistance during this investigation. I would like to thank Dr. Joseph H. Rule, my thesis director, without his invaluable supervision and direction this work would never have been completed. To Dr. G. Richard Whittecar, his assistance, both in the field and in the office is greatly appreciated. His insight and suggestions on many aspects of this work was especially helpful. Dr. Dennis A. Darby's careful review, and his valuable criticisms and suggestions regarding this work has been most appreciated.

I would like to thank the City of Chesapeake for funding the installation of monitoring wells, and thanks to Mr. Jim Garrett for assistance in the drilling operation.

I would like to express my gratitude to the faculty, staff, and graduate students of the Geological Science Department, especially those who, at one time or another, aided me with my field or laboratory work. Special thanks to Mr. Charlie Fox, Ms. Jean Ashmore, and Ms. Linda Ruf for their assistance over the years.

I am greatly indebted to my parents for their unwavering support they have given me. I can never express my full gratitude for all they have done.

To my wife, Velja McMillan, who not only has tolerated the long hours I have devoted to this research, but has actively participated in all of its aspects. She has

enthusiastically worked both in the field and laboratory with me, and is the typist of this document. Her willingness to take on many of the responsibilities of running a household enabled me to have more time to work on my research is a sign of her love and committtment to me.

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INTRODUCTION

Sanitary landfills and open dumps have been and still are the most widely used methods for disposal of municipal solid waste (MSW). The sanitary landfill, introduced in the 1930's, is considered the safest, most efficient method for land-based disposal of solid waste. However, many studies in recent years have demonstrated the landfill's potential for degradation of groundwater quality around the landfill (Qasim and Burchinal, 1970; Fungaroli, 1971; Chain and DeWalle, 1976; Johansen and Cocozza, 1977; Landreth, 1978; Gibb et al., 1981; Lu et al., 1981). The majority of these studies involved landfills with their bases in the unsaturated zone, which tends to restrict movement of the leachate.

Composition and volume of leachate generated by landfills is highly unpredictable due to variations in landfill design, operation, and stabilization. The following factors are most important in determining the composition and volume of leachate generated:

1. landfill age
2. waste composition
3. landfill design and operation
4. local climate
5. local hydrologic conditions
6. characteristics of the underlying soil or sediment

Of these factors, landfill age has the greatest influence on leacheate composition (Qasim and Burchinal, 1970; Chain and

DeWalle, 1976; Johnansen and Carlson, 1976; Lu et al., 1981).

The major constitutents of most MSW disposal facilities are paper and other wood products, vegetable matter, animal wastes, metal, glass, and ash. The principle pollutants from these wastes are soluble organic and nitrogenous compounds. These contaminants are typically measured as Biological Oxygen Demand (BOD), or Total Organic Carbon (TOC) plus Chemical Oxygen Demand (COD), and Total Kjeldahl Nitrogen (TKN). In addition to the organic compounds, a host of inorganic ions are commonly found in leachate. Ions of relatively low toxicity include: Na, K, Ca, Mg, Mn, Zn, Fe, NH_4, Cl, SO_4, PO_4, and HCO_3. Pb, Ni, Cu, Cd, Ba, Hg, Cr, B, CN, F, NO_3, As, and Se are ions of relatively high toxicity (many of which are site specific). A complete listing of parameters used as leachate indicators is in Table 1.

Effects of landfill age for several of these parameters are well summarized by Chain and DeWalle, (1976, 1977). Decreases in ratios of COD/TOC, BOD/TOC, and SO_4/Cl with age reflect changes in organic matter composition. These decreasing ratio trends and increases in pH and Eh result from rapid biodegration of free volatile fatty acids, leaving relatively stable, high molecular weight carbohydrate complexes and inorganic ions.

TABLE 1. Leachate Indicators (Fenn and Cocozza, 1977)

PHYSICAL	CHEMICAL		BIOLOGICAL
	ORGANIC	INORGANIC	
Appearance pH Oxidation-Reduction Potential Conductivity Color Turbidity Temperature Odor	Phenols Chemical Oxygen Demand (COD) Total Organic Carbon (TOC) Volatile Acids Tannins, Lignins Organic-N Ether Soluble (oil & grease) MBAS Organic Functional Groups as Required Chlorinated Hydrocarbons	Total Bicarbonate Solids (TSS, TDS) Volatile Solids Chloride Sulfate Phosphate Alkalinity and Acidity Nitrate-N Nitrite-N Ammonia-N Sodium Potassium Calcium Magnesium Hardness Heavy Metals (Pb, Cu, Ni, Cr, Zn, Cd, Fe, Mn, Si, Hg, As, Se, Ba, Ag) Cyanide Fluoride	Biochemical Oxygen Demand (BOD) Coliform Bacteria (Total, fecal; fecal streptococcus) Standard Plate Count

consequence, landfills in these regions are often located in or adjacent to coastal marshlands. These site locations present a monitoring problem as well as causing degradation of groundwater and estuarine waters (MacGregor et al., 1980; Lee et al., 1982).

Complications arise when pH and chloride are used as leachate indicators in a tidal marsh situation. Change in pH or increase in Cl from ambient groundwater concentrations due to leachate would be indistinguishable from intrusion of saline water from the ocean or tidal channels. Little, if any, research has been published on the movement and effects of leachate in coastal marshlands.

FEDERAL REGULATIONS

Until recently, wetlands (both fresh and saline) were either filled with dredge spoil to make the land suitable for development or used as an economically attractive site for disposal of both solid and liquid wastes. Much of the nation's wetlands has been destroyed or adversly impacted by such use. Land use within or adjacent to wetlands has been only loosely regulated at the Federal, State, and local levels. However, in the past 20 years, all levels of government have begun to show increasing concern over the nation's wetlands. One of the most significant steps at the federal level to regulate land use around wetlands was passage of the Resource Conservation and Recovery Act (RCRA) in 1976. The RCRA provides for direct, centralized regulation of all solid waste disposal in the United States under joint Federal and State control. This act is to be administered by the Environmental Protection Agency (EPA) pending completion of regulations and guidelines. Another major step toward regulation of landuse around wetlands was the 1977 revision of Section 404 of the Clean Water Act. In this revision, jurisdiction over permits for dredging and filling in wetlands was granted to the U.S. Army Corps of Engineers. Implementation of the 404 permit program is presently pending completion of the EPA's wetland impact assessment. Problems yet to be resolved are prediction of landuse impacts on wetlands, individually as well as in conjunction with other activities; assessment of impacts on an area-wide versus site-specific basis; and assessment of impacts from exempt or unregulated activities around wetlands (Thibodeau, 1981; U.S. EPA, 1979; MacGregor et al., 1980; Nelson, 1983).

PURPOSE

The objective of this study is to establish the suitability of pH and chloride as leachate indicators in groundwaters with naturally high salinities. If these parameters prove to be unsuitable, applicability of other selected parameters will be evaluated. Those which best fit the criteria stated in the introduction for potential leachate indicators will be considered the most viable alternatives to pH and chloride for routine monitoring purposes.

In order to meet this objective, factors in addition to groundwater geochemistry surrounding the Chesapeake Landfill are considered. An approximation of the transmissivity and direction of groundwater flow as well as grain size and thickness of the aquifer influenced by the landfill were evaluated. Tidal fluctuation and seasonal change were examined, as well, in order to evaluate their influence on those parameters studied.

STUDY SITE

The Chesapeake Landfill is a municipal solid waste disposal facility located in the southeastern coastal plain of Virginia and has been in operation since the mid 1960's. The site overlies a tidal marsh, approximately 100 meters south of the Intracoastal Waterway. Dredge spoils separate the landfill from the waterway to the north. To the east and south is a sandy loam soil and to the west is a tidal marsh (Figure 1 & 2). The dredge spoil is a medium-sorted, fine sand directly overlying the marsh clay-muck. An abundance of shell fragments and a high concentration of iron oxide-coated sand are found adjacent to the landfill. The dredge material is two meters thick wear the landfill tapers to one meter toward the waterway. A berm consisting of boulders and dredge spoil lines a portion of the river bank.

The water table aquifer ranges from less than a meter to three meters below the surface and extends seven to ten meters in depth where it contacts the Chowan River Formation.

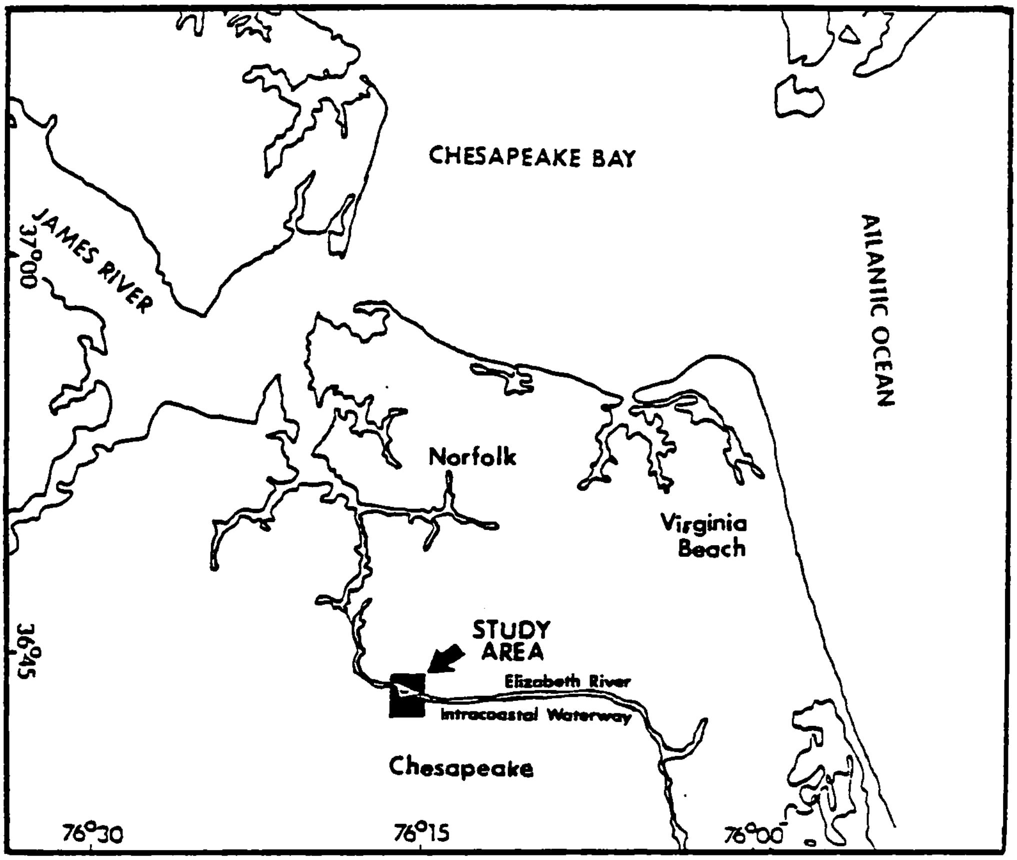


Figure 1. Map of Study Area in relation to the regional geography.

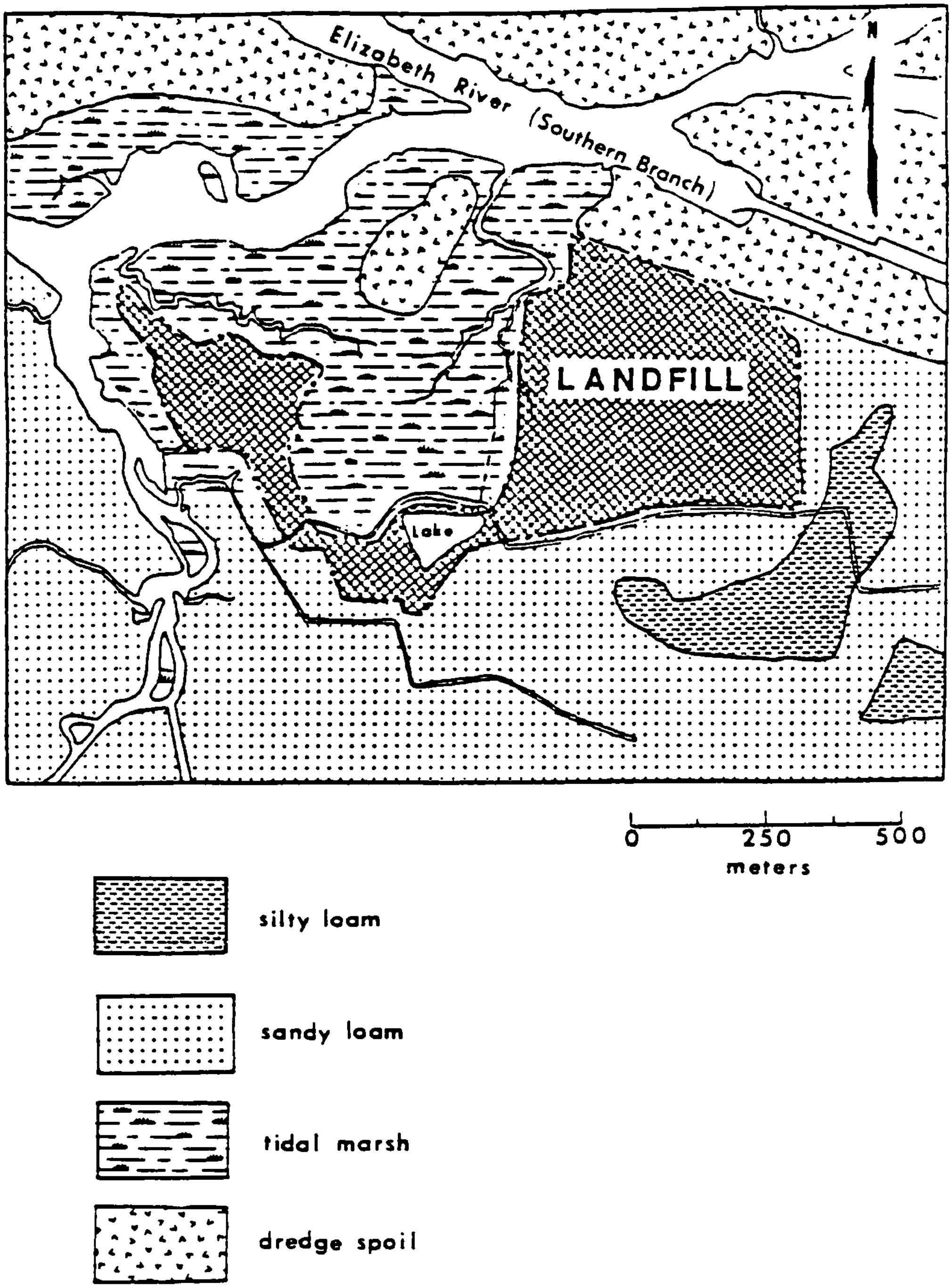


Figure 2. Map of landfill and adjacent areas showing the distribution of the soil types (from Henry et al 1958).

Between the landfill and waterway this aquifer is semi-confined, separated from the dredge spoil by marsh clay. General direction of groundwater flow is north, toward the waterway. The water table aquifer consists of fine to medium sand, generally increasing in size with depth (Appendix A). Shells are abundant in this unit, with greater concentrations toward the base. Transmissivity values for this aquifer range from 1,400 gpd/ft to 2,600 gpd/ft (Siudyla et al., 1981).

The landfill base is located several feet beneath the water table. The original mode of operation was to trench and dewater while refuse was deposited and compacted. Initial dumping was in the eastern portion of the landfill, with progressive filling toward the west. Presently, refuse is being placed over the older portion of the landfill. Two wells, placed at 7 1/2 meters depth, are currently being monitored by the city at irregular intervals for leachate. The parameters measured for these wells are pH and Cl. Several studies have suggested that salt water intrusion from the waterway may tend to mask high chloride levels due to leachate in the groundwater (Virginia State Water Control Board, unpublished data; Rule, 1979; Rule, unpublished data; McMillan, 1981).

PREVIOUS STUDIES

Studies of the Chesapeake Landfill conducted by Rule (1979) involved eight sample sites (Figure 3). The samples were taken by peristaltic pump and tygon tubing. Levels of

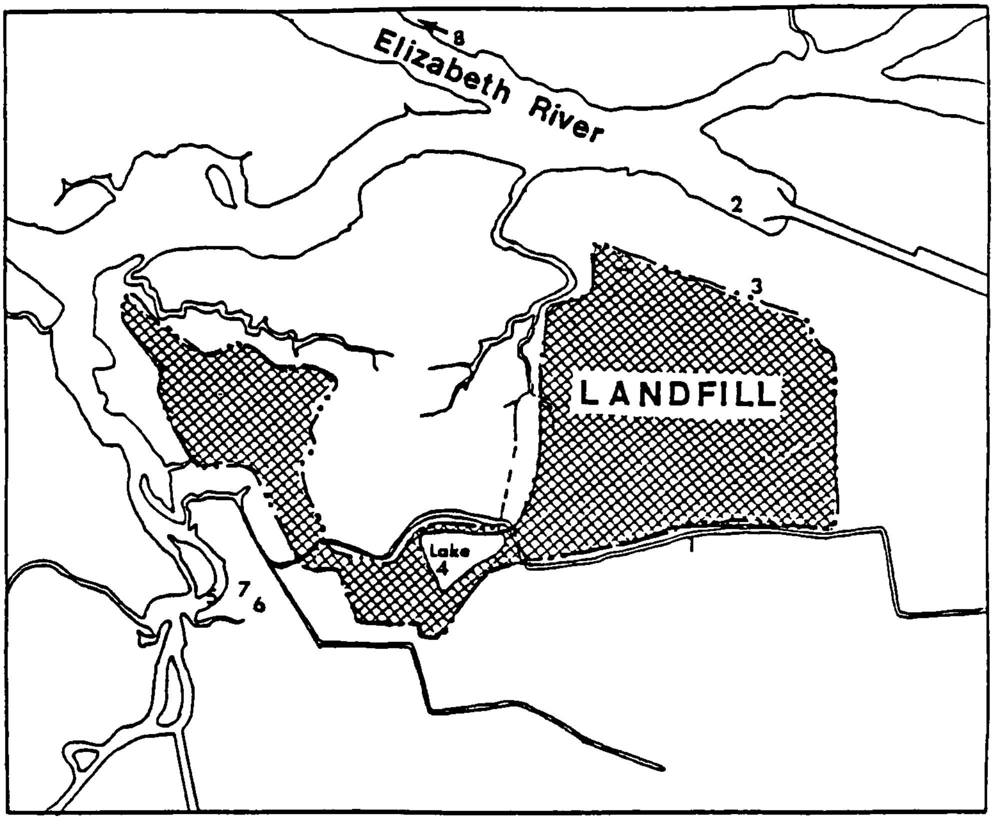


Figure 3. Sample locations used by Rule (1979).

pH and Eh were determined in the field and the samples for metal analysis were field-filtered through a 0.45 micron membrane, then acidified with 1:1 HNO_3. Coliform samples were cooled on ice and planted within six hours after sampling. The samples for metals analysis were digested in the lab using distilled HNO_3 and reagent grade HCL, in accordance with EPA methods (U.S. Environmental Protection Agency, 1974). Thirteen parameters were measured: pH, Eh, total and dissolved solids, total and fecal coliforms, Cl, Cd, Cr, Cu, Ni, Pb, and Zn. For the metals, both total and dissolved concentrations were determined. The results of the analyses indicated several monitoring problems. The monitoring wells were cased in galvanized metal, which could potentially produce anomalously high metal concentrations (note concentration of Zn, Appendix B, sites 1 and 3). The study also showed high Cl levels near the canal indicating possible saltwater intrusion (Appendix B, site 3). If the salinity of the groundwater was greater than the leachate, a density-separated flow would result in which leachate would flow above the monitoring well points. In addition, naturally high Cl levels in the groundwater would tend to mask Cl levels in the leachate.

The vertical positions of the wells (sites 1 and 3) within the aquifer may also present problems in leachate monitoring. The well points were placed at a depth of 8 meters. A well log is not available, so the positions of the well points relative to the base of the aquifer are unknown.

Preliminary research conducted by McMillan (1981) involved installation of eight pressure-vaccuum lysimeters in a transect between the landfill and waterway. Two lysimeters were installed at each well site, at depths of one and three meters (Figure 4). No control wells were used in this study. The wells were all hand-augered. Due to hydraulic pressure and incompetency of the sand it was impossible to auger deeper than three meters. The three meter well at site D did not penetrate through the clay layer, so no sample could be obtained from this lysimeter. There were five sampling periods from March through July 1981. Eh, pH, conductivity and salinity were determined in the field. Samples taken for metal analysis were field-preserved with 1:1 HNO_3, the other samples received either no preservative or H_2SO_4, and were cooled to four degrees centigrade. All analyses were conducted in accordance with EPA Methods (U.S. Environmental Protection Agency, 1974). The parameters measured in this study were pH, Eh, conductivity, salinity, TKN, NO_3, NO_2, Cl, total PO_4, and metals (Na, K, Ca, Mg, Fe, Mn, Cu, and Pb).

The following parameters showed distinctive trends (Appendix B):

1. Conductivity, salinity, Na, Cl, and Mg concentrations for the upper wells showed a general decrease away from the waterway, increasing again toward the landfill. The concentrations increased from the Elizabeth River toward the landfill for the deeper wells.

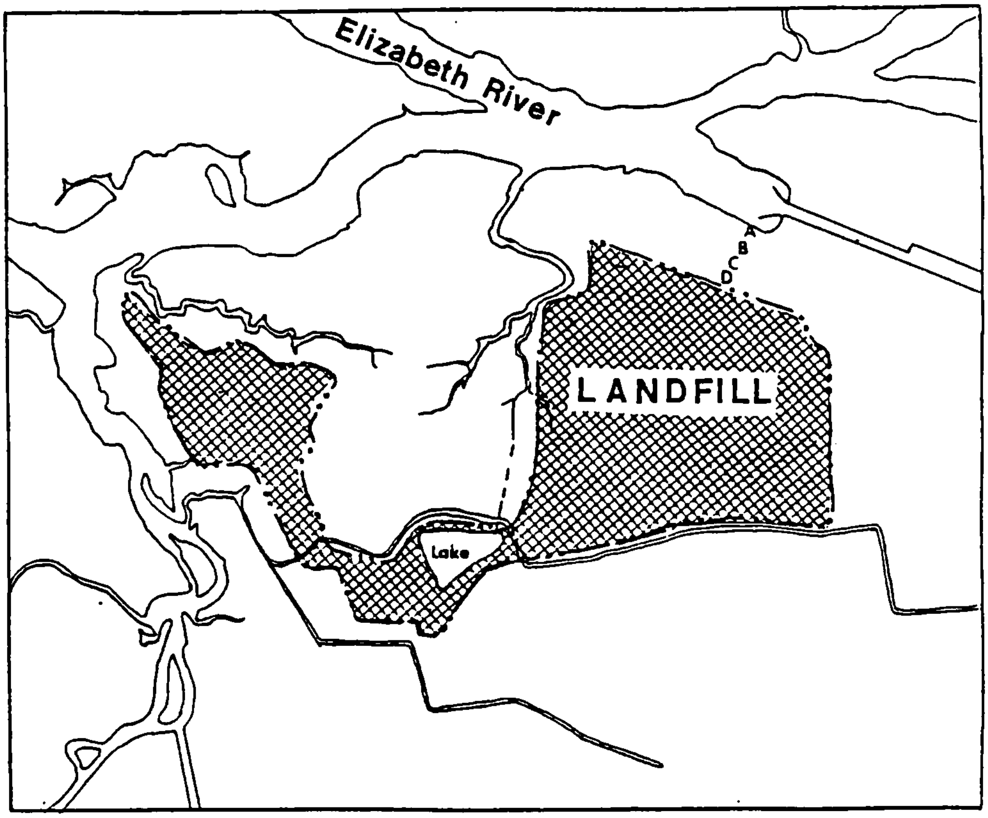


Figure 4. Sample locations from preliminary monitoring study by McMillan (1981).

2. Concentrations of TKN, K, Fe, and Ca increased toward the landfill for both upper and deeper wells.

3. NO_2 increased by several orders of magnitude toward the landfill for the one meter wells. The only significant concentration for the three meter wells is at site C (no sample was obtained at three meters for site D).

4. PO_4 was the only parameter to decrease in concentration toward the landfill for the one meter wells. Concentrations for the three meter wells were insignificant when compared with the one meter wells.

Results from the preliminary study by McMillan, (1981), tentatively indicated that influence from the canal resulted in high salinity, conductivity, Na, Cl, and Mg in the dredge spoil. In addition to the parameters above, leachate from the landfill appeared to contribute high TKN, K, Fe, NO_3 and Ca concentrations for both the dredge spoil and the water table aquifer. A portion of the Ca concentration for the upper wells may be attributed to the shell fragments present in the sediment at sites C and D. However, no shells were found in the water table aquifer even though high Ca concentrations were present.

METHODS AND PROCEDURES

FIELD METHODS AND LABORATORY PROCEDURES

The monitoring wells for the present study consist of 1-1/4 inch PVC pipe with a three foot fine screened well point. These wells were installed by a wash boring rig, backfilled with sand from the aquifer and sealed at the top with bentonite. Due to problems with collapsing sand, the ten meter wells were jetted in and as a result are not capped at the bottom of the screen. Logs were taken for each well site (Appendix A). Elevations of the top of all wells were measured by transit and stadia rod.

Each site has a well positioned at the upper (three meters depth) and lower (ten meters depth) boundary of the aquifer. Upper wells are designated by a subscripted 1 and lower wells by a subscripted 2. Two parallel transects are located to the north of the landfill (Figure 5). Three well sites per transect are spaced at approximately twenty five meter intervals, from river to landfill. An additional monitoring site is installed to the west of the older portion of the landfill (site G), as well as three control sites (H, I, J) to the east and south. Additional water samples were taken from the tidal creek adjacent to site G and from the river, near site A.

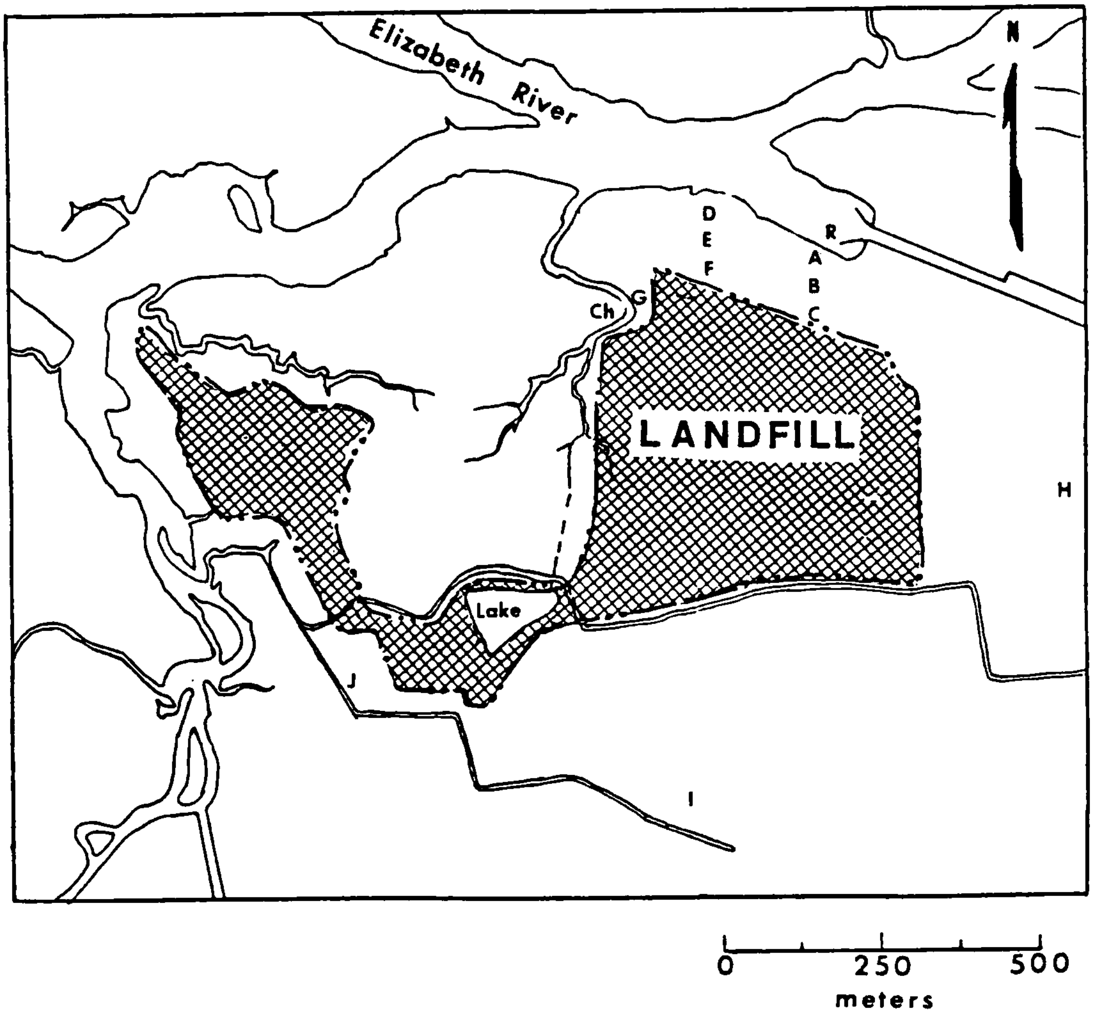


Figure 5. Locations of well sites and surface water sites.

Changes in hydraulic head, conductivity, salinity, and temperature for sites A, C, and I were measured hourly over a 30 hour period in October 1982. Water levels in all wells were measured in October 1982 and August 1983.

Sample collection and preservation were conducted in accordance with EPA recommended procedures (Fenn et al., 1977; U.S. EPA, 1979; Gibb et at., 1981). Samples were withdrawn using a peristaltic pump, after drawing off at least 15 liters from each well to insure a fresh sample. Due to very slow recharge for wells E_2 and I_2, there was no initial flushing of these wells. Samples were stored in one-liter linear polyethylene (LPE) bottles and immediately placed on ice. Separate samples in 60 ml bottles were taken for pH and Eh and measured on site. Conductivity, salinity, and temperature were taken by lowering a conductivity cell and temperature thermistor probe in each well after samples were obtained. Within 24 hours after sampling, the samples were centrifuged at 6,000 rpm for five minutes to remove suspended particles. Samples for metal analysis were then stored in 150 ml LPE bottles and preserved with redistilled reagent grade HNO_3 at a pH of less than 2. Samples to be analyzed for phosphates, nitrate, and Total Kjeldahl Nitrogen (TKN) were stored in 250 ml bottles and preserved with reagent grade H_2SO_4 at a pH of less than 2. Samples preserved with either H_2SO_4 or no preservative were stored at a temperature of 4 degrees centigrade.

The parameters measured were pH, Eh, conductivity, salinity, hardness, temperature, TPO_4, OPO_4, NO_3, NO_2, TKN, SO_4, Cl, and metals (Ca, Na, Mg, Mn, K, Zn, and Fe). Samples were taken on a monthly basis from August 1982 through October 1983, for a total of twelve sampling periods. A Ag Ag/Cl combination electrode was used to measure pH; a platinum redox electrode for Eh; and conductivity, salinity, and temperature was measured by a YSI model 33 SCT meter. Both total and orthophosphate were determined by the ascorbic acid method, with a persulfate digestion prior to addition of the coloring reagent for total phosphate. Nitrate was measured by the brucine method, nitrite by the sulfanilamide method, TKN by digestion and ammonia probe, sulfate through the barium chloride turbidometric method, and chloride by either solid state electrode or argentometric method. Metals were determined with a Perkin Elmer 603 atomic absorption spectrophotometer.

The most ubiquitous interferences were highly colored samples from sites C_1, F_1, G_1, and G_2 and colloidal suspension (primarily from sites E_2 and I_2). Parameters which relied on spectrophotometric methods (nitrate, nitrite, total phosphate, and orthophosphate) or turbidimetric methods (sulfate) in determining their concentrations were affected most. To correct for these interferences for nitrate, duplicate samples were digested without the coloring reagent, and used as blanks. For nitrite, total phosphate, and orthophosphate, initial absorbances were read before addition of the coloring reagents and used as blanks. Interferences from color and colloids were corrected for sulfate by initial absorbance readings, after addition to the conditioning reagent and before addition of the barium chloride. The standard addition method was used for several samples during most analyses to verify that any interferences present were not significant. In addition to standard additions, EPA quality control samples were used for most parameters for at least one sampling period.

Samples were stored and preserved in accordance with EPA recommended procedures (U.S. Environmental Protection Agency, 1979). All analyses were conducted in accordance with Standard Methods (APHA-AWWA-APCF, 1975) and within the alloted sample holding time as specificed by EPA methods.

STATISTICAL METHODS

Statistical evaluation of the data was divided into three parts. First, variance within the data was discussed utilizing descriptive statistics and one-way analysis of variance (ANOVA). Second, multiple regression was used to examine any possible relationship between tidal fluctuation and variance within a parameter. If tidal fluctuation was found to significantly influence a parameter, the regression equation was used to correct for this influence. Third, factor analysis was used to summarize the interrelationships among the variables, condensing the variance within the original data into a few variables (factors) as an aid in conceptualization. The statistical package SAS (Statistical

Analysis System) compiled by SAS Institute Inc., was used to obtain solutions to the ANOVA, multiple regression, and factor models.

Before results from the ANOVA could be interpreted, potential failure of two basic assumptions had to be considered: within-cell observations are normally distributed about the mean; and variance between cell means is homogeneous. The Barlett-Box F-statistic was used to test homogeneity of variance. Often, when non-normal distributions occur, heterogeneity of variance between means (heteroscedastcity) also occur (Cochran, 1947). This non-normal distribution and heterogeneity of variance errors are usually a direct function of the cell's mean value ($S^2=m+S^2{}_m$). A lognormal transformation may be used to correct this failure. Barlett (1947) considered this to be the appropriate transformation for non-normal sample variances. If the lognormal transform significantly improves the distribution of error terms, then the transformed data would be used in all subsequent analyses. This transformation has been widely used in geochemistry to correct for pseudo lognormal distributions, however, application of this method is still in dispute (Link and Koch, 1975, Chapman, 1976; 1977; Miesh, 1977).

Because the data for the ANOVA model was not a balanced design, a general linear model was used. This model is considered a good alternative to the more traditional method of mean square ratios where the cell block design is unbalanced (Wesolowsky, 1976; Snedecor and Cochran, 1980). Tukey's range test was used to aid in identifying anomalously high or low cells (sample sites or dates) for parameters where the null hypothesis was rejected.

The independent variables used for the multiple regression analysis was tidal fluctuation, seasonal variation, and horizontal and vertical distance. Tidal levels were taken from tide tables for Sewells Point, Norfolk, and corrected for the Great Bridge locks. Tidal fluctuation was recorded as a fraction ranging from 0.0 to 1.0, with 0.0 representing low tide; 1.0 equal to high tide; and 0.5 as slack tide. Seasonal variation (summer, winter, spring, and fall) was represented by three dummy variables. Distances were also recorded as dummy variables, two for depth (upper wells, lower wells, and surface water) and four for horizontal distance (surface water, adjacent to landfill, adjacent to surface water, between landfill and surface water, and control wells).

The SAS procedure REG was used for a least-squares fit to the regression models. All independent variables were used as regressors in the first model. Subsequent models used separate dummy variable groups (seasonal variation, vertical distance, and horizontal distance) as the regressor variables.

The approach to factor analysis of the groundwater data was to use the most simplistic model (principal components) and derive principal factors (or axes) and scores for the total data set. The loadings for each factor were then compared to the corresponding score groupings. If separation of the scores into groups was geologically interpretable in relation to their loadings, a higher level of factor analysis was employed. The method chosen was a principle axes solution with varimax rotation (vector analysis). Results from this analysis were then compared with the principle component solution to see if it increased resolution without changing the basic distribution of the factor scores.

Standarized data was used to calculate factor scores, therefore the sum of all observations for each variable has a mean of zero and unit variance. The scores were grouped according to their original sample sites and plotted as bargraphs with 95% confidence bands for each site.

Pairwise deletion of observations was used to produce the correlation matrix. For calculating factor scores, only observations with missing variables contributing to less than 10% of the vector's magnitude were used. Missing values for included observations were replaced by sample means. Since these values have little influence on the resulting score, this method was considered best for retaining a maximum amount of information with mininal sacrifice to error.

RESULTS AND DISCUSSION

STRATIGRAPHY AND HYDROGEOLOGY

The landfill overlies tidal marsh deposits approximately 100m south of the intracoastal waterway (southern branch of the Elizabeth River). Dredge spoils overlying a marsh clay-much separate the landfill from the waterway to the north. To the east and south is a sandy loam soil and to the west is a tidal marsh. The stratigraphy of the water table aquifer is known from wash boring logs taken when the monitoring wells were installed and from particle size analyses of sediments taken from two sites north of the landfill. These data form the basis for a generalized fence diagram (Figure 6) and a more detailed cross-section (Figure 7).

The underlying aquifer is fairly homogeneous both vertically and horizontally. It consists of medium to fine, moderately sorted sand and is strongly fine-skewed and leptokurtic. Parallel to the northern edge of the landfill and extending no more than 50m north of the landfill is a 30 to 60 cm thick silt-clay lens at a depth of seven meters. This lens was recorded in well logs at sites C, F and G, and borehole 1 (Figures 6 and 7). Shell fragments are noticeably more abundant with depth. From the well logs, sediments around control wells H, I and J

▩ Landfill

▨ Sandy Loam Soil

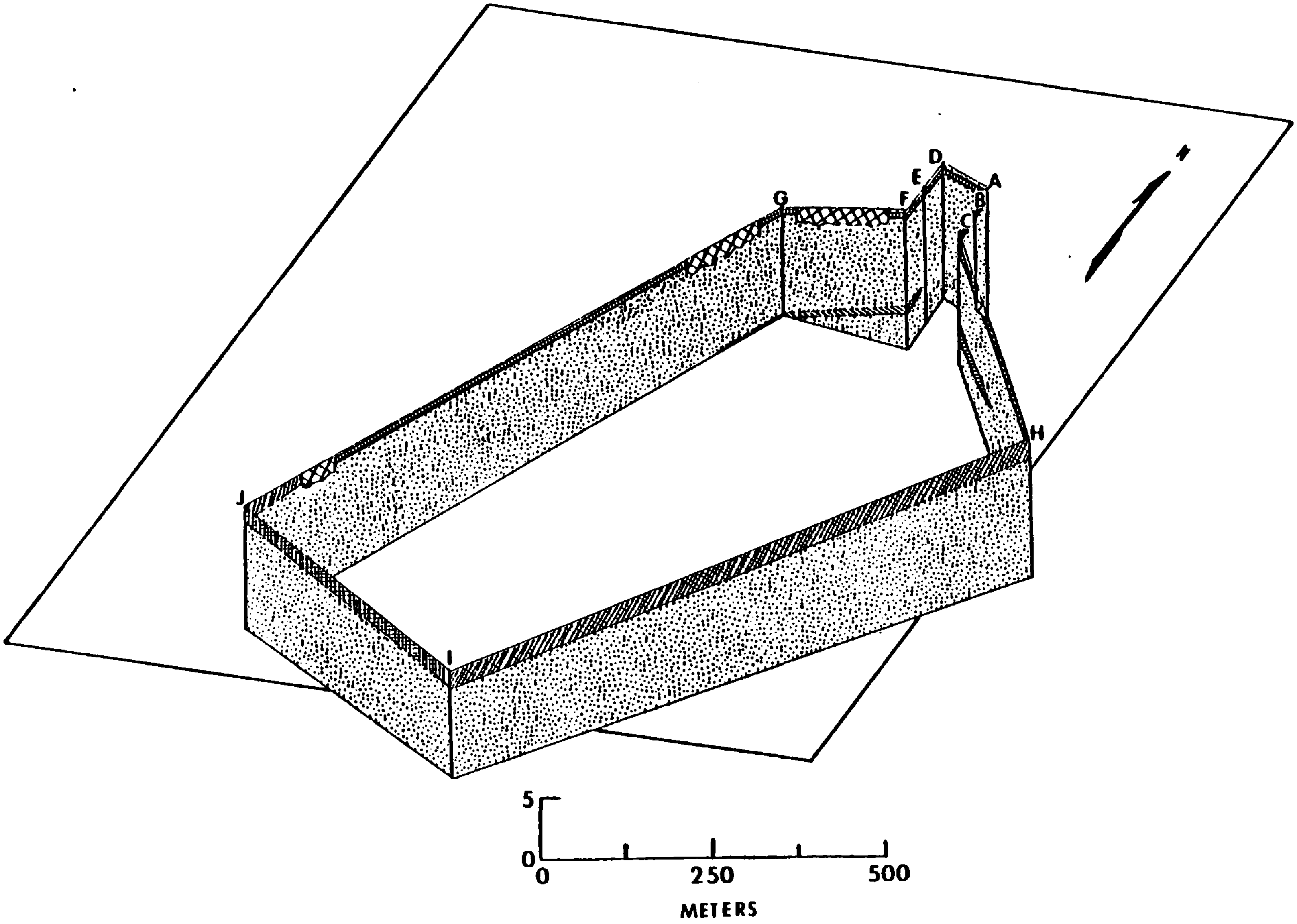
▦ Marsh

░ Medium Sand

▒ Fine Sand

▧ Clay

Figure 6. Generalized fence diagram connecting all boreholes around the Chesapeake Landfill.



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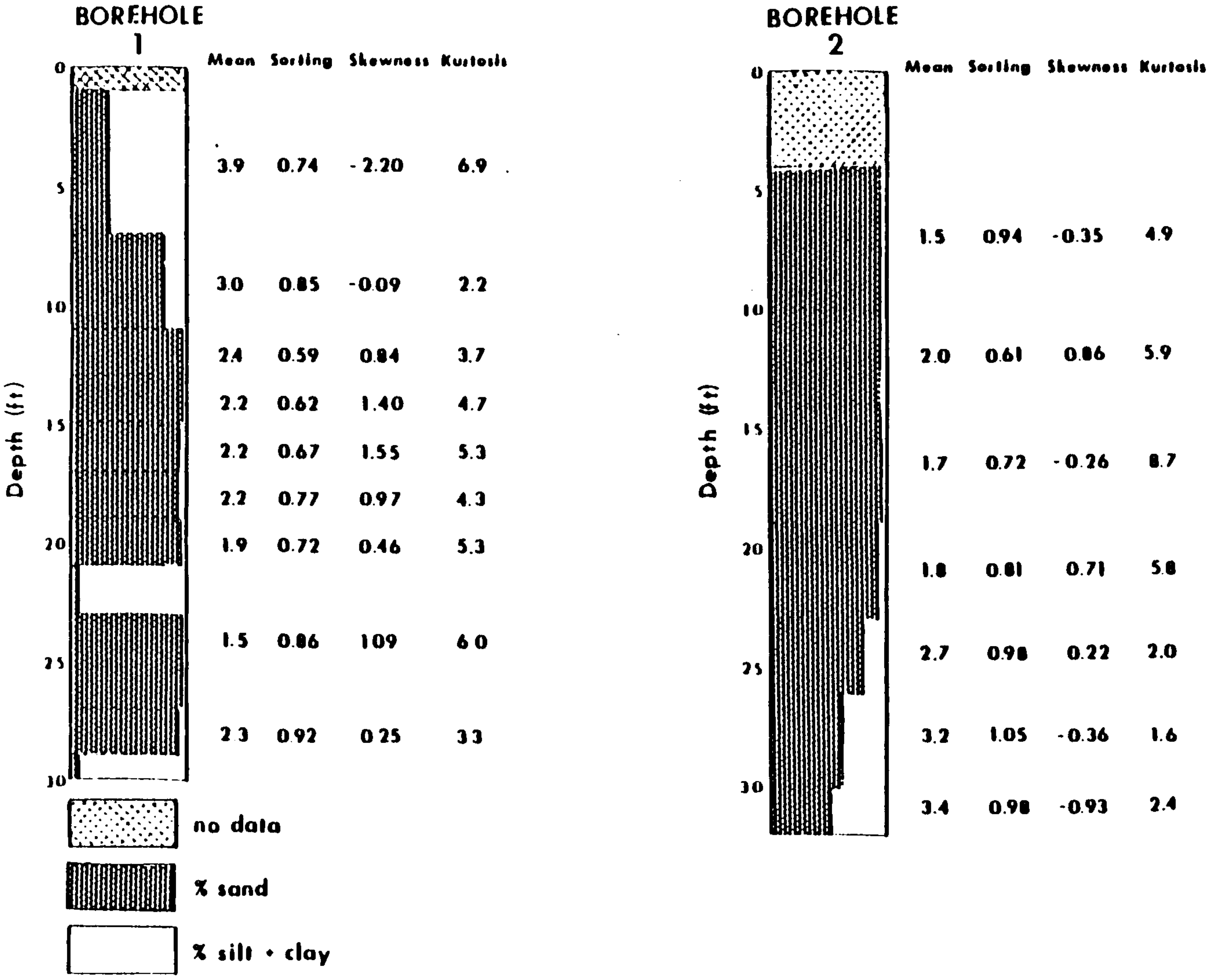


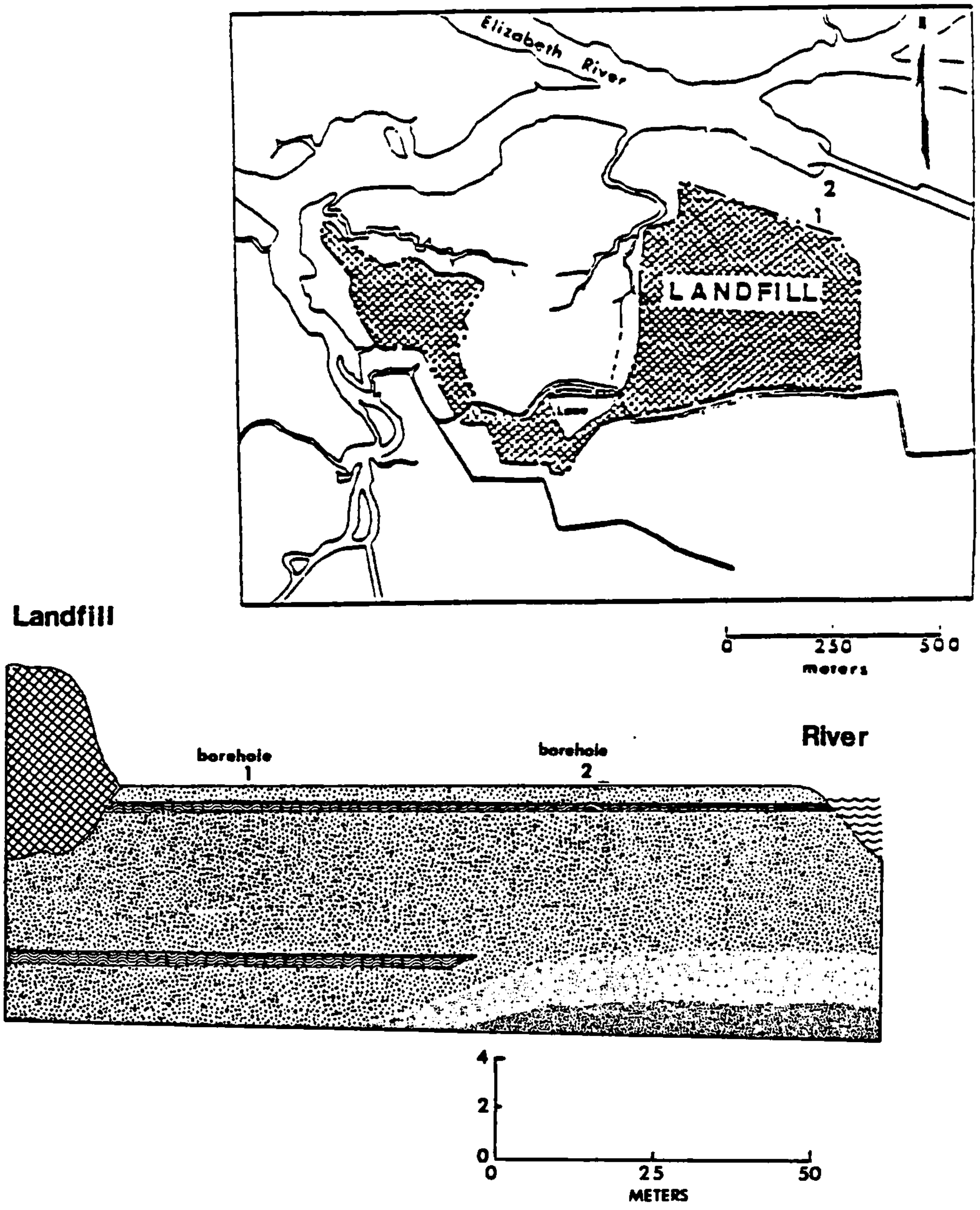
BOREHOLE 1

Mean	Sorting	Skewness	Kurtosis
3.9	0.74	-2.20	6.9
3.0	0.85	-0.09	2.2
2.4	0.59	0.84	3.7
2.2	0.62	1.40	4.7
2.2	0.67	1.55	5.3
2.2	0.77	0.97	4.3
1.9	0.72	0.46	5.3
1.5	0.86	1.09	6.0
2.3	0.92	0.25	3.3

BOREHOLE 2

Mean	Sorting	Skewness	Kurtosis
1.5	0.94	-0.35	4.9
2.0	0.61	0.86	5.9
1.7	0.72	-0.26	8.7
1.8	0.81	0.71	5.8
2.7	0.98	0.22	2.0
3.2	1.05	-0.36	1.6
3.4	0.98	-0.93	2.4

Figure 7. Sand size distribution from two wells drilled north of the landfill.


Elizabeth River
2
1
LANDFILL
0 250 500
meters
Landfill
borehole
1
borehole
2
River
4
2
0
0 25 50
METERS

appear to be homogeneous both vertically and horizontally, consisting of medium-fine sand.

Water levels in the wells seem to reflect the degree of variability in sediment textures. For example, most wells refilled with water almost instantly when purged during water sampling. Also, differences in water levels between upper and lower wells (verical hydraulic gradient) was constant and relatively small (0.01) between most well sites. Both of these observations indicaate that the aquifer is reasonably homogeneous with a high permeability. Not all well sites, however, are so uniform. At wells I2 and E2, refill rates are much slower than at other sites and there is a greater decrease in hydraulic head from upper (3 meters) to lower well (10 meters). Well F_1 also refilled noticably slower than most wells, though not to the same extent as E_2 and I_2. The slow refill rates at wells E_2 and I_2 and the high vertical gradients at these sites are most likely due to a decrease in grain size with depth. This would indicate heterogeneity in the sediment texture is greater than indicated by the wash boring logs.

Due to the general lack of regional topographic relief and the gentle, broad slopes of coastal terraces in the area, it was assumed prior to this study that groundwater flow is generally north and the hydraulic gradient is low. In order to test this assumption, water levels were measured for all wells in October, 1982 at the same point in the tidal cycle (Appendix A). Wells along the N-S transect A-I were monitored semi-hourly over a 30 hour period in October, 1982. Use of piezometers rather than wells screened through the entire aquifer presented a problem in evaluating the overall horizontal gradient in that the measured water levels were influenced by vertical hydraulic gradients in addition to horizontal gradients. The horizontal gradient for the upper wells is generally north (NW to NE), toward the river, averaging around 0.005. There is almost no horizontal gradient for the lower (10 meter) wells (<0.001). The vertical gradient for all sites (except J) decreased with depth. A three dimensional hydrologic cross-section shows the head distributuion in the aquifer north of the landfill (Figure 8). Effects of groundwater mounding in the eastern half of the landfill and the apparent decrease in grain size toward the west is primarily responsible for the cone, or plume shaped distribution centered around transect A-C. The higher mounding along transect A-C is due to the topographically higher (5 to 7 meters) elevation of the eastern portion of the landfill over the western half. This area is also currently active (unvegetated), with sandy dredge spoil used for cover.

Water levels measured semi-hourly over a thirty hour period along the north-south transect A-I show a decrease in the hydraulic gradient toward the river (Figure 9). The lateral gradient is much higher north of the landfill than elsewhere due to effects of groundwater mounding in the landfill. Tidal fluctuation in the adjacent river

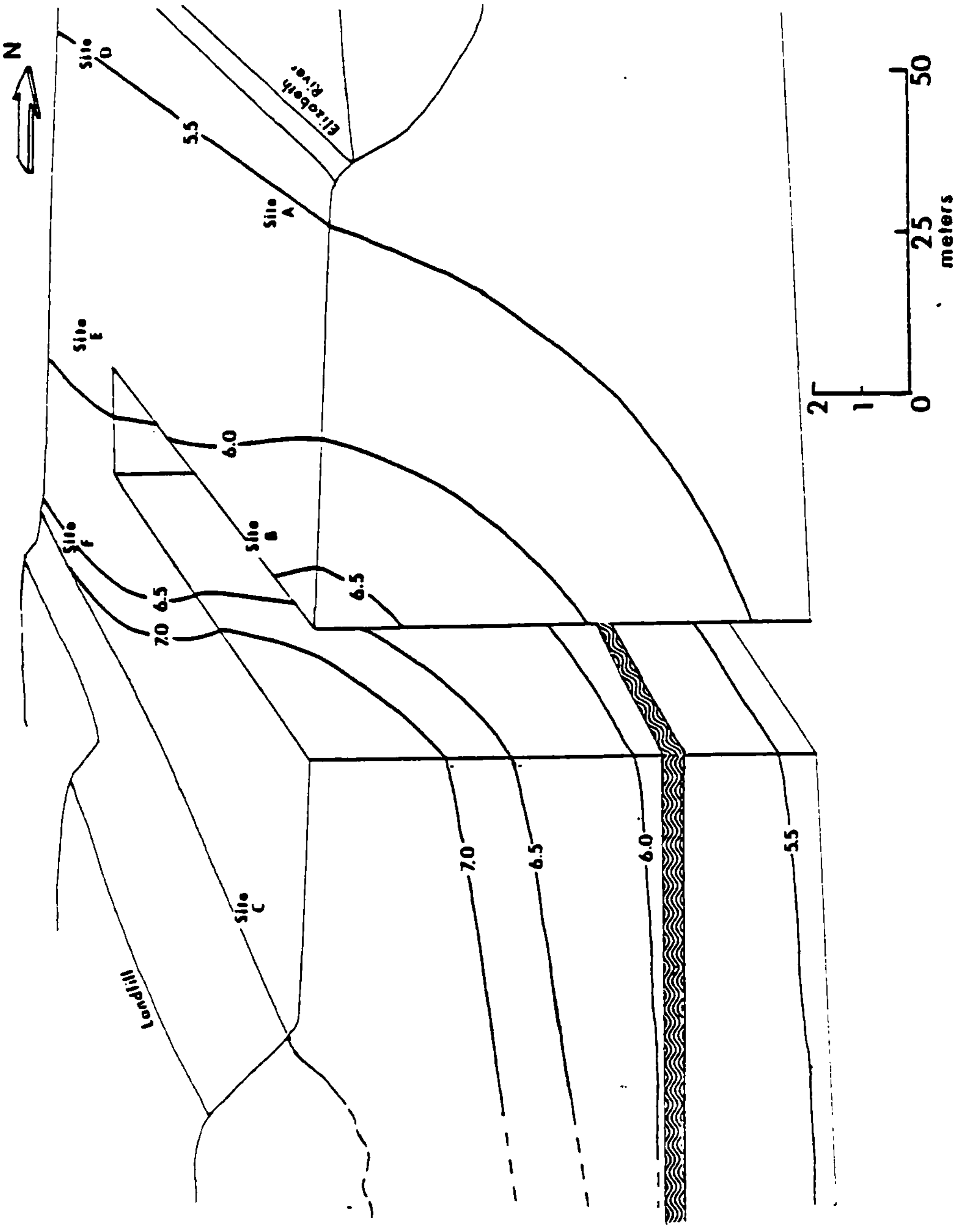


Figure 8. Three dimensional hydrogeologic cross section of the head distribution north of the Chesapeake Landfill.

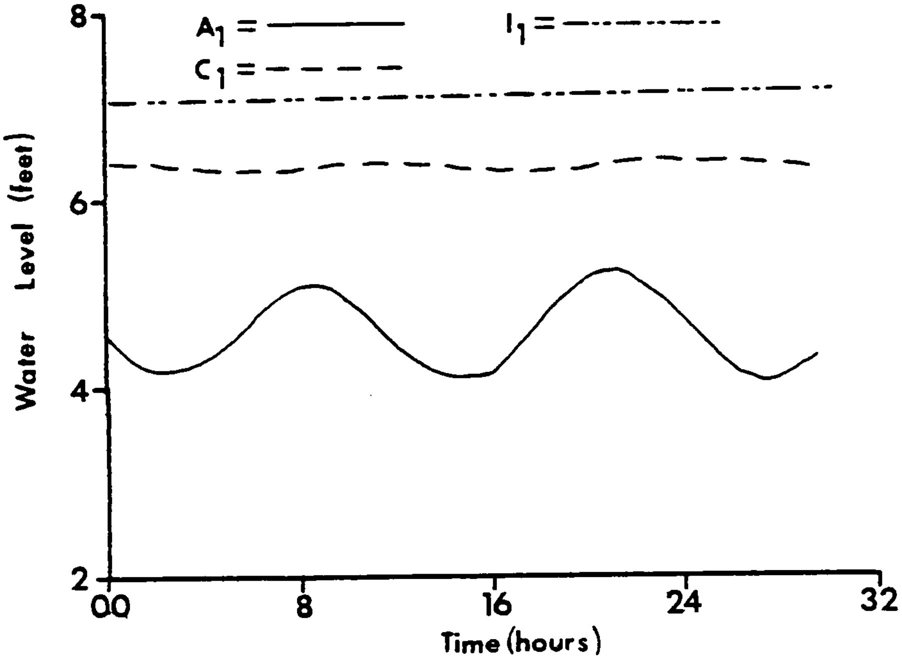


Figure 9. Fluctuation in measured water levels over a thirty hour period for wells A_1, C_1, and I_1.

significantly affected the water levels measured at site A, and to a lesser extent influenced water heights measured at well C_1. This fluctuation in the hydraulic head along transect A-C resulted in a regular fluctuation of the gradient along that transect. The gradient toward the river was at a minimum at high tide (0.004) and at a maximum at low tide (0.008). At no point in the tidal cycles did the gradient reverse itself. From these data, it appears that the rate of groundwater flow toward the river will change over a tidal cycle. It also appears that throughout a complete tidal cycle, net flow of groundwater remains in a northerly direction.

CHEMICAL ANALYSES

Simple statistics such as means and standard deviations, as well as one way ANOVAs, are used as an aid in interpreting the results. All ANOVA tests used F=0.01 as the rejection limit for the null hypothesis. Heterogeneity of variance between sample sites for every variable was the most serious failure of an assumption for ANOVA. This non-normal distribution of errors was a direct function of its mean value ($S^2=m+S^2{}_m$). In an attempt to correct for this failure, a lognormal transformation was used for each variable. After the data was lognormally transformed, homogeniety of variance was improved, though not enough for the variance to be normally distributed (Barlett-Box F statistic). Using lognormally transformed data did not signifcantly change results of the F statistic for ANOVA over the original data. The original data set was used in subsequent discussions because of the controversy over applying a lognormal transform to a pseudo lognormal distribution; the failure of the lognormal transform to significantly improve homogeneity of variance; and the unbiased estimate provided by non-transformed data for sample means and standard deviations. Use of nontransformed data, even though the assumptions of homogenety of error variance and normally distributed error failed, is supported (in a qualified way) by Cochran (1947). Cochran noted that non-normality and heterogenity of errors often do not greatly effect the validity of the F-test. He does point out, though, that the results should be regarded as approximative rather than exact.

pH

Values for pH varied significantly between sites, ranging from 4.70 at well I_1 to 7.45 in the channel. From Figure 10, an obvious pattern of increasing pH with depth for every well site can be seen. To test if this increase was significant, a series of Student's T-tests were used, comparing the upper wells with their corresponding lower well. For every site (excluding B and C) the null hypothesis that the two means were equal was rejected at the 0.01 significance level. The increase in pH as well as higher concentrations of Ca with depth (see calcium, pg. 43) was probably caused by increased shelly material with depth. The higher pH at sites B and C relative to the

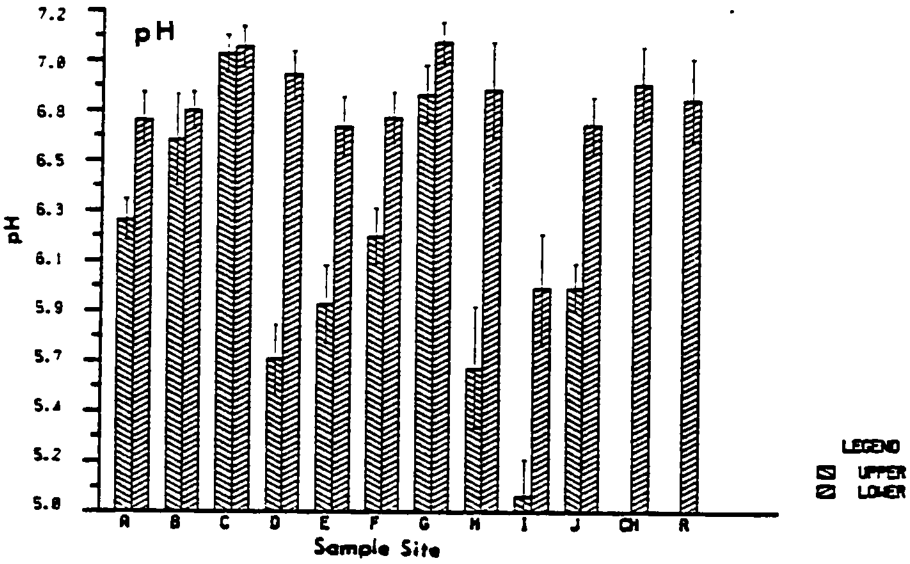


Figure 10. Bar graph of site means for pH, vertical lines represent 95% confidence ranges.

corresponding lower wells was likely due to leachate movement from the landfill. The clay lens separating upper from lower well at site C would prevent movement of leachate vertically.

Well B_1 appears to show some seasonal cyclicity in pH; higher in the summer months and lower in the winter. The cause of cyclicity (also observed in several other parameters at B_1) is attributed to leachate migration. Microbial decomposition of organic wastes would increase due to the rise in temperature and rainfall during the summer months. The sandy nature of the landfill cover allows for quick infiltration of rainwater, and the high water table (above the landfill's base) allows for direct contact between the leachate and groundwater. Rapid infiltration of rainwater and the high water table appears to overide the effects of increased evapotranspiration. This suggestion cannot be confirmed until water budget approximations are made for the area around the landfill.

Eh

Eh ranged from -210mv at site G_2 to +255mv at site I_1. Both sample means and means by sample period (date) varied significantly. Samples taken during the period between June and July appear to be significantly more oxidizing than the other dates (Figure 11). Winter samples are on the average more reducing, with a minimum for the December

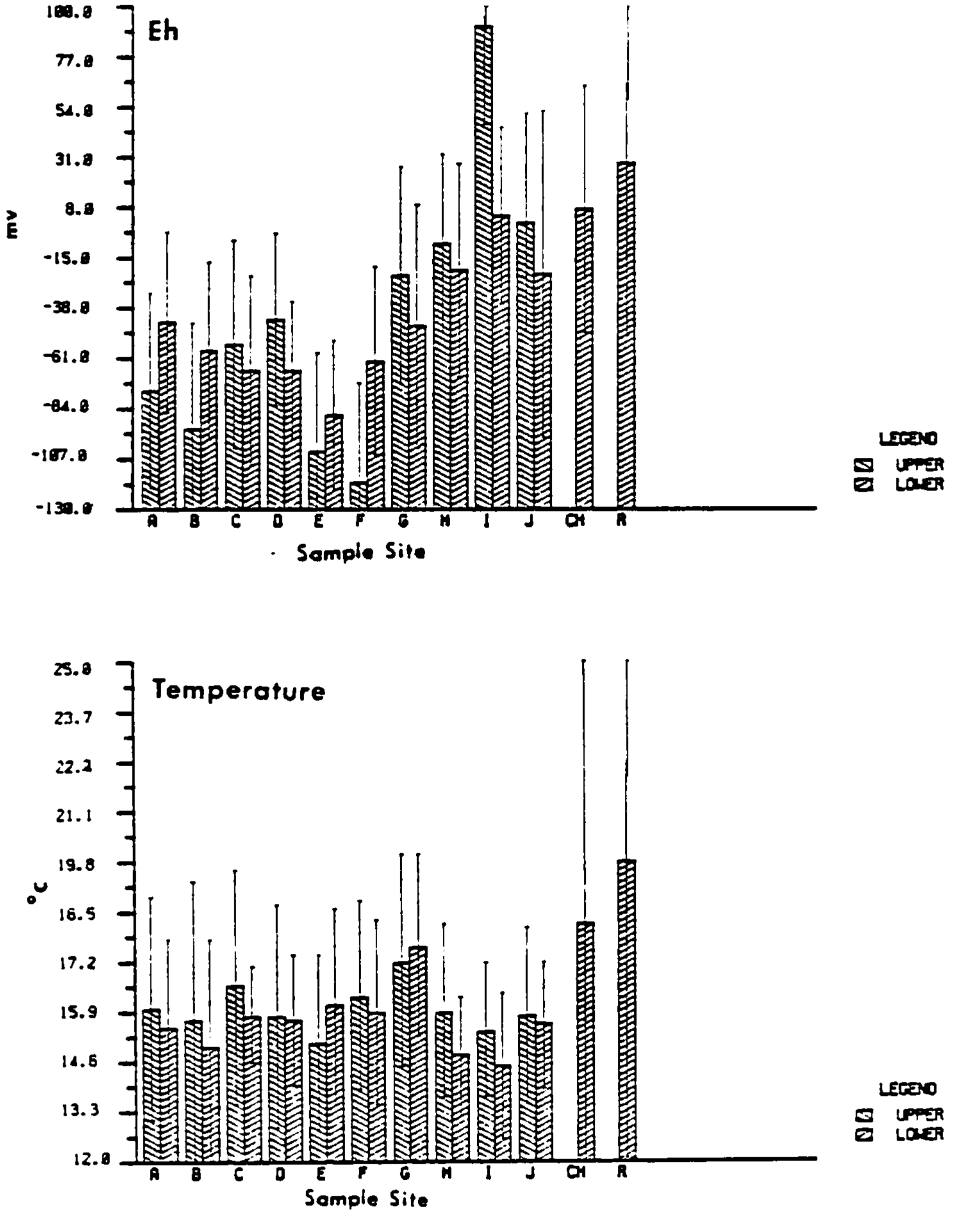


Figure 11. Bar graphs of site means for Eh and temperature, vertical lines represent 95% confidence ranges.

sampling. Site I_1 is the most oxidized site (X=91 ±71mv) and F_1 the most reduced (X=-118 ±68mv).

Temperature

Temperature, though not considered to be a very sensitive measure for presence of leachate, was included early (10-28-82) in the research only because it was required for determining salinity and was already available. Data missing for the period 12-20-82 was due to instrument problems, resulting in the additional loss of conductivity and salinity measurements.

Temperature for the well sites varied from 9°C for sites B_1 and F_1 in January, and B_2 in March to 25°C at site C_1 in July. The surface water sites, as expected, had a larger range, from 6°C in January to 31°C in July. There was significant variation in both site and sample period means. Temperature for the upper wells were generally higher than lower wells, though not significantly. Variation in temperature by date was seasonally cyclic, with a low of 11°C and a high of 21°C (Figure 11).

Conductivity and Salinity

There was a wide variation in conductivity between sites, ranging from 100 μmohs at site I_1 and I_2 to 22,000 mohs in the river. Salinity varied from ‰ for the control wells to 14‰ in the surface water. Mean conductivities and salinities are graphed on Figure 12. Site means for both conductivity and salinity were significantly different. The control wells all have mean conductivities at least an

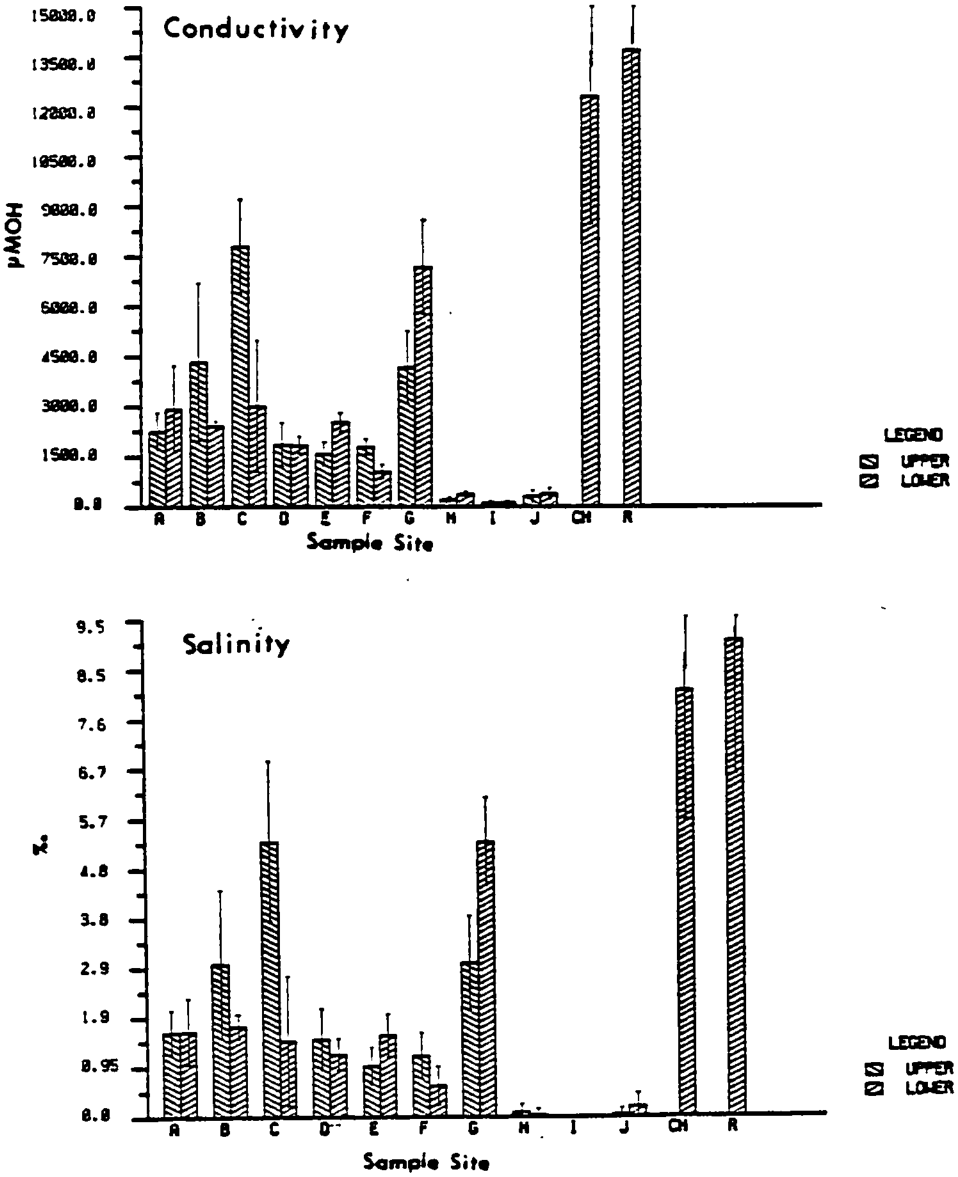
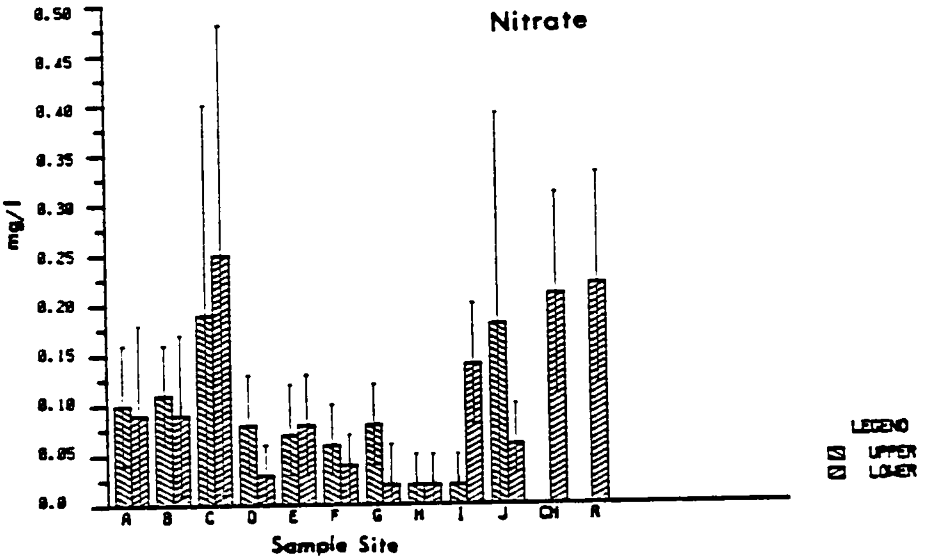


Figure 12. Bar graphs of site means for conductivity and salinity, vertical lines represent 95% confidence ranges.

order of magnitude less than the other sites. There is a significantly sharp decrease in salinity and conductivity away from the landfill for transect A_1-C_1 and a slight U-shaped trend along transect D_1-F_1, decreasing away from both landfill and river. Though this decrease along transect D_1-F_1 is not statistically significant, locally it does suggest both brackish surface water and leachate might influence groundwater salinity and conductivity. Well G_2 had a significantly higher concentration than G_1, probably due to a density-separated flow of leachate from the landfill. The large variation in salinity and conductivity at B_1 results from seasonal influence on the leachate plume. Concentrations for the summer months are significantly higher than for the winter months.

Nitrate and Nitrite

Both nitrate and nitrite were present in low concentrations. Nitrate varied from a maximum of 1.0 mg/l at J_1 in October to BDL (<0.1 mg/l) for all sites. Nitrite had a maximum concentration of 85 ug/l for the channel in October and a minimum of BDL (<1 ųg/l) at most sites. Nitrate's mean by site was less than 0.3 mg/l and nitrite's was less than 10 ųg/l (except the channel, with a mean of 32 ųg/l). Nitrate tended to be higher in concentration for sites C_1 and C_2, I_2, J_1, and surface water (Figure 13). Nitrite on the other hand was much higher in the channel (with a correspondingly larger variance).



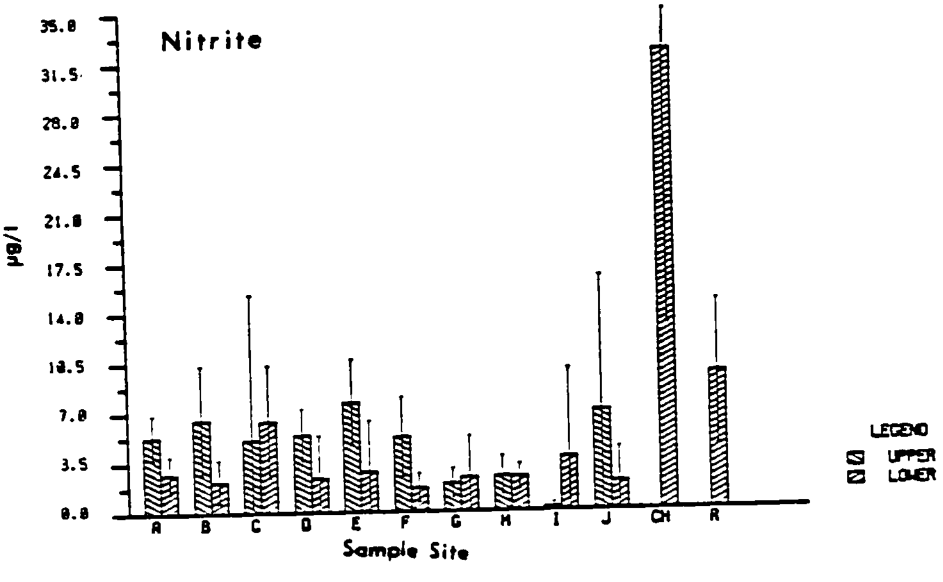


Figure 13. Bar graphs of site means for nitrate and nitrite, vertical lines represent 95% confidence ranges.

Total Kjeldahal Nitrogen

Total Kjeldahal Nitrogen (TKN) varied by over three orders of magnitude between sites (Figure 14). TKN decreased significantly away from the landfill for both transects A_1-C_1 and D_1-F_1. Site C_1 (adjacent to the active portion of the landfill) had by far the highest concentration of TKN, followed by G_2 then G_1. The higher concentration in the lower well (G_2) at site G supports the idea of a density separated flow of leachate from the landfill. Concentration of TKN in all surface waters was negligable. Well C_2 had a relatively high mean (58 mg/l) due to the anomalously high concentration from the first sample date. This anomalous value resulted from leakage through the clay lense separating C_1 from C_2, while drilling well C_2 in August 1982. Site B_1 may show seasonal variability in TKN, but unfortunately, the data set is incomplete. Data missing for dates 10-28-82, 6-3-83, and 8-28-83 was the result of problems with the ammonia probe. The analysis for 3-6-83 was not conducted within the alloted holding time.

Total and Orthophosphate

Orthophosphate accounted for a majority of the phosphate in the ground and surface waters (Figure 15), averaging greater than 50% for all sites. Total phosphate, however, was low for all surface and groundwater sites, ranging from less than 0.01 to 2.4 mg/l at C_1. Sites most likely to be influenced by leachate (C_1 and G_2) had the highest averages

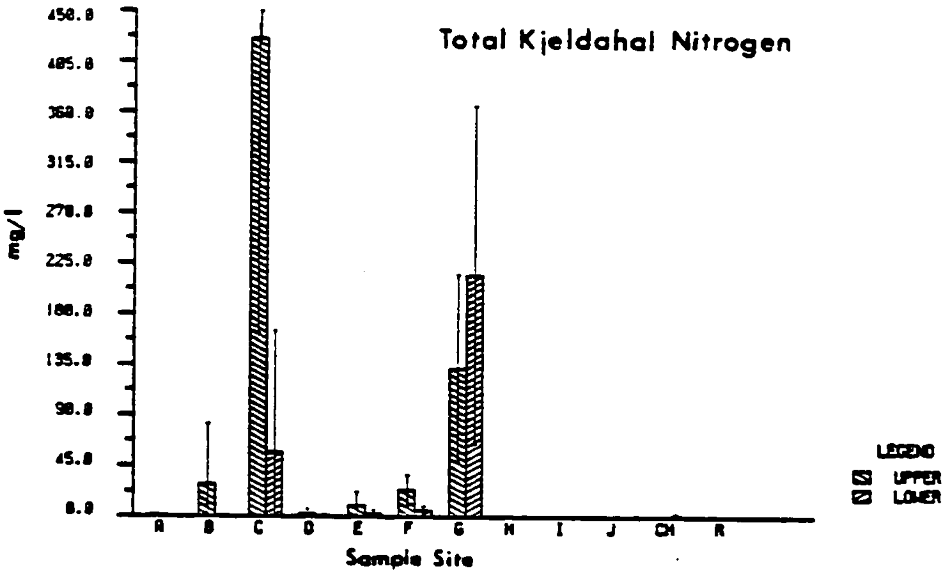


Figure 14. Bar graph of site means for total kjeldahal nitrogen, vertical lines represent 95% confidence ranges.

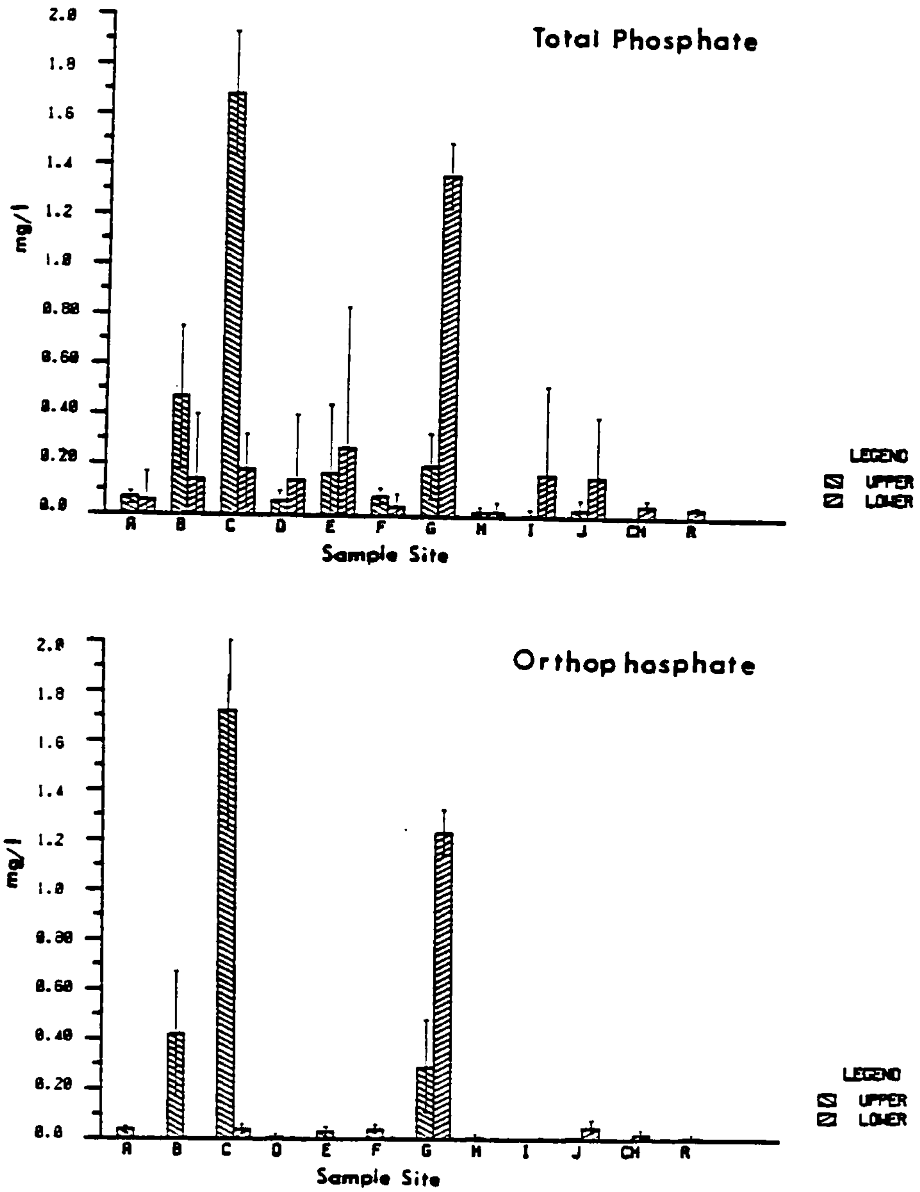


Figure 15. Bar graphs of site means for total phosphate and orthophosphate, vertical lines represent 95% confidence ranges.

of all sites, in most cases at least an order of magnitude greater than the other sites.

ANOVA indicated at least one site mean was significantly different from all others. Tukey's Studentized range test by site separated C_1 and G_2 from the other sites for both total and orthophosphate. B_1 and G_1 separated from other sites, with very little overlap, for orthophosphate.

Site B_1 has a relatively high mean and standard deviation (Appendix D), and on inspection of the total data set, there may be some seasonal variations at this site for both total and orthophosphate. Student's T-test for the summer samples (July and August) against the other dates indicated that the summer concentrations were significantly higher than winter concentrations. This increase in phosphate at site B_1 is interpreted as an increase in leachate production during the summer months.

Phosphate was found in significantly greater concentrations at sites C_1, G_2, B_1 and G_1. The higher concentration for the lower well at site G may indicate a density separated flow of leachate from the landfill. Phosphate in the surface waters was low (averaging less than 0.01 mg/l).

Sulfate

Sulfate concentrations were relatively low for the groundwater samples, averaging 15 mg/l, while surface water sites were over an order of magnitude higher, averaging 454 mg/l (Figure 16).

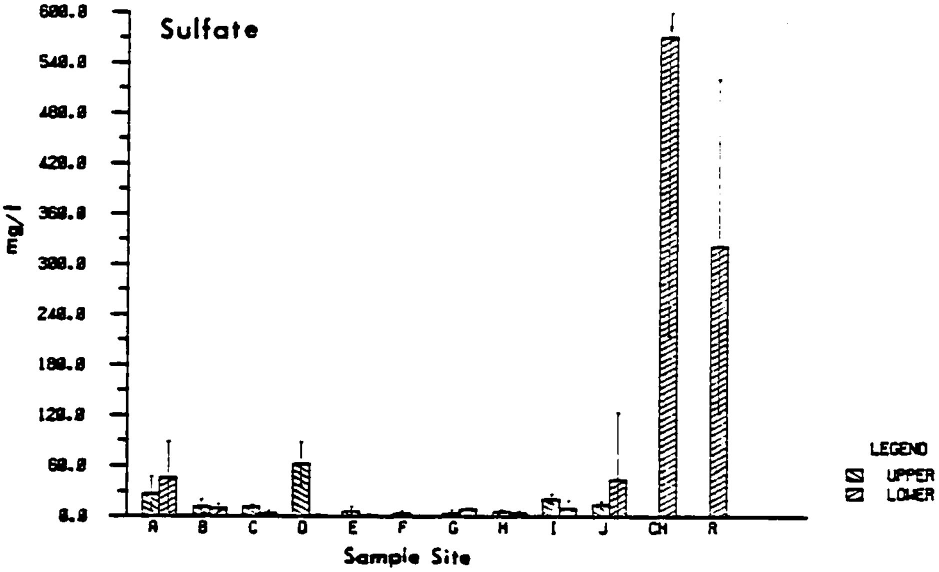


Figure 16. Bar graph of site means for sulfate, vertical lines represent 95% confidence ranges.

ANOVA rejected the null hypothesis that all site means were equal, and Tukey's range test significantly separated surface water from groundwater sites. The range test also separated the channel and river sites. Separation of the channel site from the river site was due to the anomalously large difference in measured sulfate concentrations for the sample taken on 10-30-83. Removal of this sample resulted in no significant difference between the channel and river sites. The heterogeneity within the channel and river sites may result from tidal fluctuations or use of the locks. This source of variance in the surface water samples was not supported by regression analysis.

Sites adjacent to the river (A_1, A_2, D_1) had higher concentrations of sulfate than the other groundwater sites, indicating influence from the surface water. Sites I and J also had elevated sulfate concentrations with the source possibly from nearby drainage ditches. The increased sulfate concentrations are not statistically significant, indicating only a trend toward higher concentrations.

Sodium and Chloride

Sodium concentration equaled chloride concentration for all sites (Figure 17; Appendix D). Site means were significantly different, with Tukey's range test separating surface from groundwater for both sodium and chloride. Groundwater sites down gradient of the landfill had much higher concentrations (at least an order of magnitude) than sites up gradient (control sites) of the landfill. Sodium

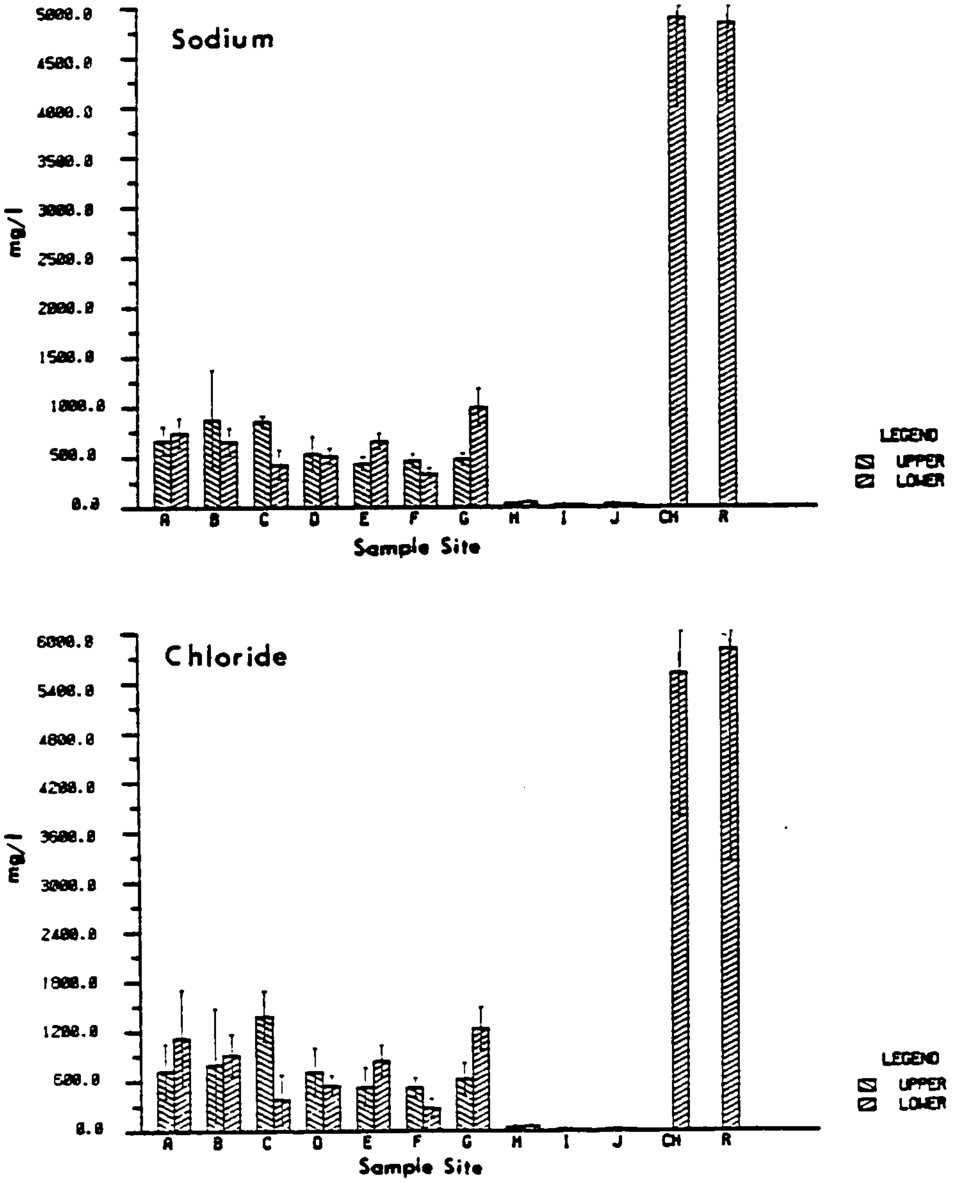


Figure 17. Bar graphs of site means for sodium and chloride, vertical lines represent 95% confidence ranges.

and chloride concentrations between the river (and channel) and landfill appear to be influenced by both the surface water and leachate. This dual influence is best illustrated along transect A-C (river to landfill) where the chloride concentration decreases toward the landfill for lower wells and increases for upper wells. The large variability at site B_1 is probably seasonally influenced, with higher concentrations in the summer months and lower concentrations in the fall through spring months (total data, Appendix C). This variability is probably due to increased leachate movement, since the surface water does not appear to significantly increase seasonally. The inverse relationship (also seen in conductivity and salinity) between upper and lower wells along transect A-C possibly represents a density separated flow, in which a denser saline wedge from the surface water extends toward the landfill and a less dense leachate plume overides the saline wedge.

Potassium

Potassium varied considerably from site to site, with a minimum of 1 mg/l at site H_1 to a maximum of 1530 mg/l at site C_1 in August. Site means varied significantly, and Tukey's range test separated C_1 and G_2, then G_1 and B_1 from the other sites. All other sites fell within the same range, including surface waters (Figure 18). Sites adjacent to and down gradient (A-G) of the landfill have means at least an order of magnitude greater than the other sites. Variability at B_1 is almost certainly seasonal, increasing

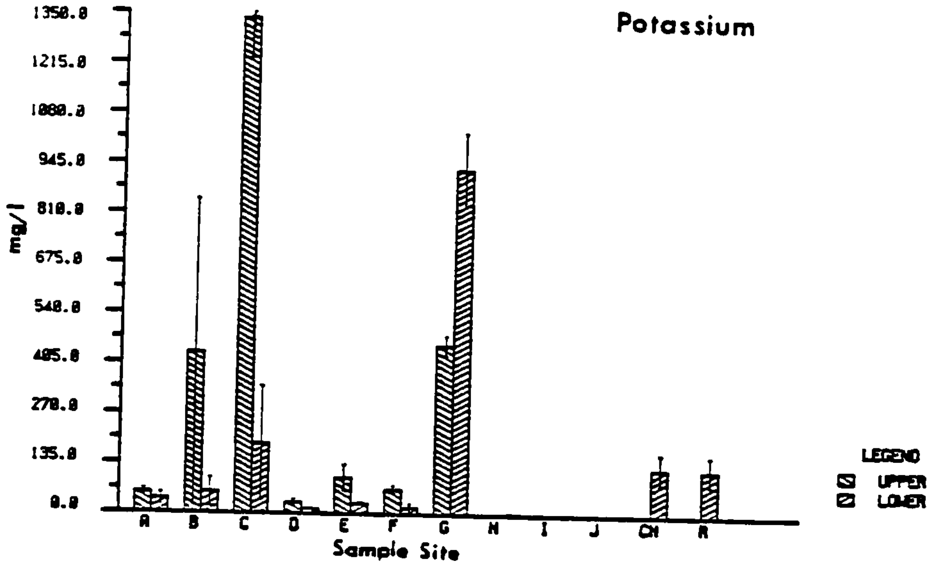


Figure 18. Bar graph of site means for potassium, vertical lines represent 95% confidence ranges.

by over an order of magnitude in the summer months (July and August). An increase in June and decrease in September and October is also apparent (Appendix (C)).

The sharp decrease in potassium along transect A-C is undoubtably due to movement of leachate. Higher levels of potassium for the lower well G would result from a density separated flow of leachate.

Calcium

Calcium varied significantly between upper and lower well means (based on Student's T test). The upper wells mean was 54 ± 36 mg/l; the lower wells mean was 108 ± 55 mg/l, and that of the surface waters was 121 ± 45 mg/l. For every groundwater site, the lower well had a higher concentration of calcium (Figure 19). This increase in calcium with depth is caused, in part, by the increase in shell material with depth. The upper wells have higher concentrations of calcium downgradient of the landfill (sites A-G) than upgradient (control sites H-J). The higher concentration of calcium at these sites may be influenced by a combination of leachate and surface water.

Though Tukey's range test did not separate any groups without overlap (except site E_2), the general trendency was for surface waters and lower well sites together with higher means, while upper well sites had lower means.

Magnesium

The concentration of magnesium is significantly higher (Student's T test) for surface waters than groundwaters.

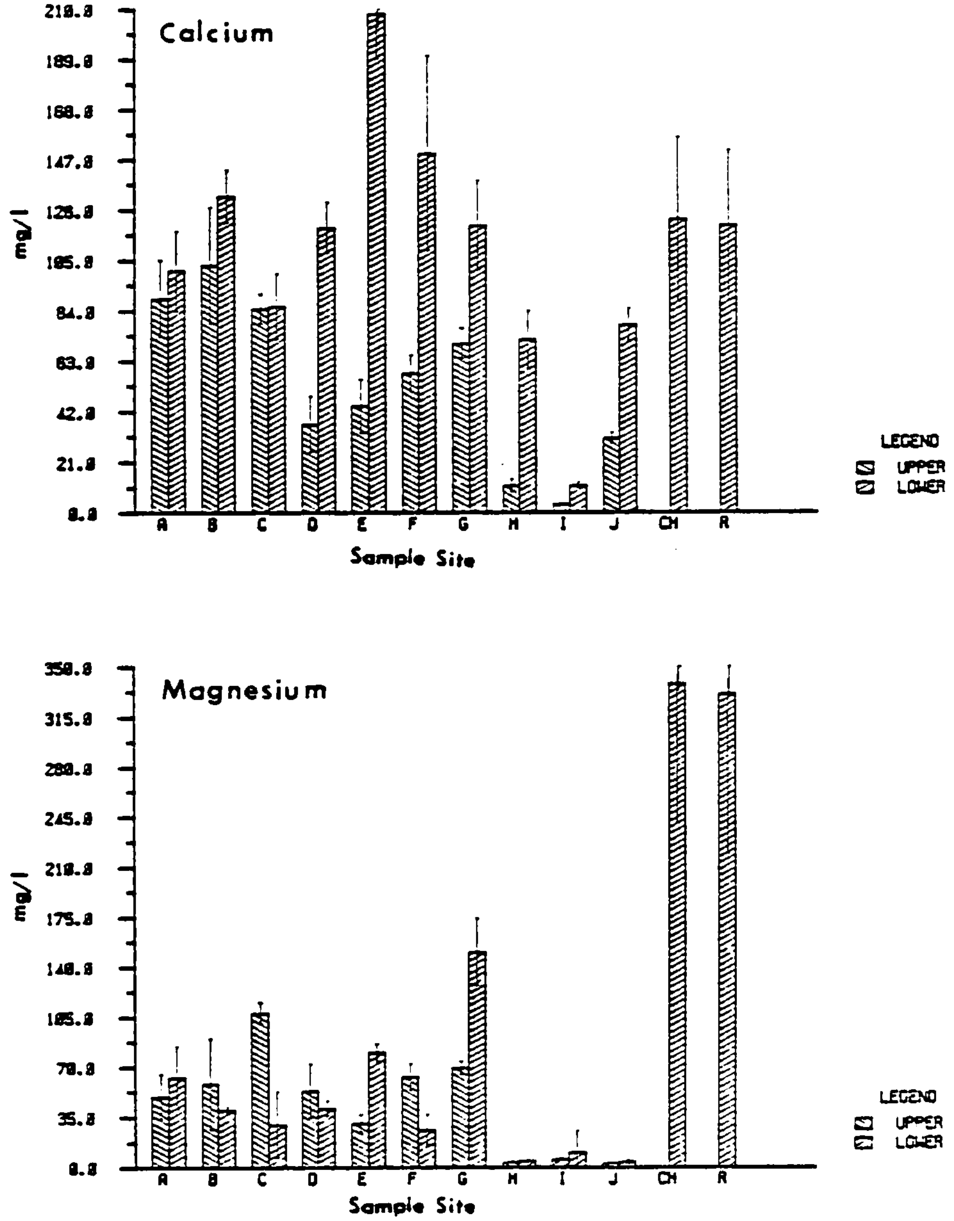


Figure 19. Bar graphs of site means for calcium and magnesium, vertical lines represent 95% confidence ranges.

Surface waters had a mean concentration of 335 ± 137 mg/l, while the groundwater samples had a mean of 46 ± 48 mg/l (Figure 19). Tukey's range test separated surface waters from groundwater without overlap. Within the groundwater sites, G_2 and C_1 separated from the other sites with very little overlap. Although the control wells did not separate from the other sites without overlap for Tukey's range test, they all had much lower means. The inversely trending concentrations between upper and lower wells along transect A-C for Na and Cl was also true for magnesium.

Iron and Manganese

Neither iron or manganese varied significantly between sites. However, iron did vary significantly over time. From inspection of the total data set (Appendix C), it can quickly be seen that for several sites (F_1, A_2, D_2, F_2, G_2, I_2 especially), the measured concentration for the first sampling period was several orders of magnitude greater than the following dates. These anomously high concentrations were the result of an inadvertent partial acid extraction of sediment not filtered out of the samples. Suspended particulates in subsequent samples were removed by centrifuging.

By removing the first sample date for both iron and manganese, variance between sites became significant, whereas variance between dates was no longer significant. Although there is no strong trends for either element, the upper wells generally have higher concentrations, with the exception of sites E_2 and I_2. High iron and manganese concentrations at these two sites is attributed to limited flushing of the well prior to sampling necessitated by low recharge rates.

Zinc

Zinc concentrations varied significantly by site. The null hypothesis was not rejected for ANOVA by site. Because the same sites which had anomously high iron and manganese concentrations (F_1, A_2, D_2, F_2, G_2 and I_2) also had high zinc concentrations, the first sample date was removed and ANOVA reexecuted. Site A wells (both upper and lower) give the only two mean concentrations significantly different from the others. A_1 had a higher concentration due to the value for date 3-6-83 (0.39 mg/l), while A_2 had consistantly higher concentrations than the other sites. A_2 was the only site to separate from the other sites by Tukey's range test.

FACTOR ANALYSIS

Principal components analysis was initially run on the data. Out of the twenty vectors extracted, five accounted for over 80% of the variance in the data, and seven accounted for over 90% of the variance (Table 2). Next, a principal axes solution was applied to the correlation matrix. Because of high communalities for several variables, the diagonal element was not replaced by communality estimates. A varimax procedure was used to

Table 2. Table of eigenvalues for the principal components method, before and after VARIMAX rotation.

EIGENVALUES

PC METHOD WITHOUT ROTATION

Factor	Eigenvalue	% Variance
1	7.13	35.6
2	3.61	18.1
3	3.14	15.7
4	1.53	7.6
5	1.28	6.4
6	0.89	4.4
7	0.71	3.6
8	0.56	2.8
9	0.33	1.7
10	0.30	1.5
11	0.24	1.2
12	0.15	0.8
13	0.14	0.7
14	0.12	0.6
15	0.09	0.4
16	0.05	0.3
17	0.01	0.0
18	0.01	0.0
19	0.00	0.0
20	0.00	0.0

PC METHOD WITH VARIMAX ROTATION

Factor	Eigenvalue	% Varience
1	6.56	39.3
2	4.02	24.1
3	3.14	18.8
4	1.60	9.6
5	1.36	8.2

TABLE 3. Table of factor loadings for the principal components method, before and after VARIMAX rotation.

Factor Loadings without Rotation

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
pH	0.48848	0.23613	-0.02371	-0.53357	-0.06337
Eh	0.07866	-0.12842	-0.15457	0.77137	-0.15606
Temp.	0.33984	0.05149	-0.18296	0.45865	-0.54977
Cond.	0.96210	-0.02097	-0.11753	0.02325	-0.08918
Salinity	0.93170	-0.19536	0.28923	-0.05591	-0.11537
Hardness	0.93269	0.00849	-0.14416	-0.05022	0.03423
Nitrate	0.23753	-0.05450	-0.02442	0.12665	0.76846
Nitrite	0.37629	-0.38677	-0.11920	0.14343	0.47015
TKN	0.36238	0.82120	-0.18222	0.20239	0.13607
Total Phos.	0.41982	0.81427	0.00520	0.01455	0.09201
Orthophos.	0.40601	0.88760	-0.11783	0.11025	0.00032
Sulfate	0.63358	-0.48822	-0.13977	0.18833	0.05991
Chloride	0.89196	-0.37167	-0.12518	-0.03448	0.04581
Sodium	0.85062	-0.36327	-0.14273	-0.01791	0.00579
Potassium	0.50231	0.78812	-0.14929	0.00459	0.07471
Calcium	0.55797	-0.03387	0.37384	-0.46923	-0.24279
Magnesium	0.94130	-0.24791	0.01382	0.03153	-0.05998
Iron	0.10263	0.06098	0.95844	0.18620	0.06261
Manganese	0.17661	0.15547	0.92691	0.15902	-0.02354
Zinc	0.14616	0.01845	0.95272	0.14842	0.08425

Rotated Factor Loadings

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
pH	0.39236	0.33161	-0.05172	-0.54363	-0.14672
Eh	0.12054	0.00320	-0.00991	0.80703	0.00045
Temp.	0.35399	0.19646	-0.06496	0.55046	-0.43942
Cond.	0.91188	0.34094	-0.00257	0.02150	-0.01204
Salinity	0.92349	0.10508	0.36102	-0.09852	-0.04908
Hardness	0.86458	0.36362	-0.03986	-0.06857	0.09195
Nitrate	0.14829	0.12226	0.04682	-0.01355	0.79199
Nitrite	0.43694	-0.14192	-0.05907	0.10148	0.56759
TKN	0.02643	0.93865	-0.03357	0.09856	0.07601
Total Phos.	0.08001	0.90336	0.11809	-0.10761	-0.00193
Orthophos.	0.05663	0.98410	0.01744	0.01412	-0.08104
Sulfate	0.75745	-0.16966	-0.06048	0.22131	0.20791
Chloride	0.96171	0.00272	-0.05029	-0.01613	0.15810
Sodium	0.92582	-0.00403	-0.06962	0.01062	0.11884
Potassium	0.17901	0.92775	-0.02682	-0.08865	-0.00242
Calcium	0.54370	0.04830	0.32999	-0.49056	-0.28962
Magnesium	0.95191	0.11243	0.10874	0.02747	0.04238
Iron	-0.01076	-0.01061	0.98495	-0.00368	0.03291
Manganese	0.03619	0.09595	0.96200	-0.02245	-0.06257
Zinc	0.04407	-0.03499	0.97490	-0.04010	0.05749

rotate the vectors, reducing the number of factors representing the data's variance from twenty to five loadings. These factors were then compared to loadings of the corresponding factors from principal components analysis. Since there was no major change in factor loadings and scores, the rotated matrix solution was used.

Factor One (Surface Water - Ground Water)

Variance accounted for by factor one was mostly between groundwater and surface water sites representing 39% of total variance in the data. Loadings, or variables, most important in determining the direction of the vector (i.e.: largest magnitude) would exhibit the most variance between the groundwater and surface water. These loadings were conductivity, salinity, hardness, chloride, sodium, and magnesium. Scores for factor one were calculated and grouped according to site (Figure 20).

The channel and river sites had significantly higher score means than the total score mean and any of the ground water sites. All ground water sites, with the exception of G_2, had means below the total mean. Because all maximum loadings were positive, it would be safe to assume that conductivity, salinity, hardness, chloride, sodium, and magnesium are present in much higher concentrations in the surface water than ground water. This observation is supported by the raw data for these parameters.

Also worth noting is the inversely related trends between upper and lower wells along transect A-C. This

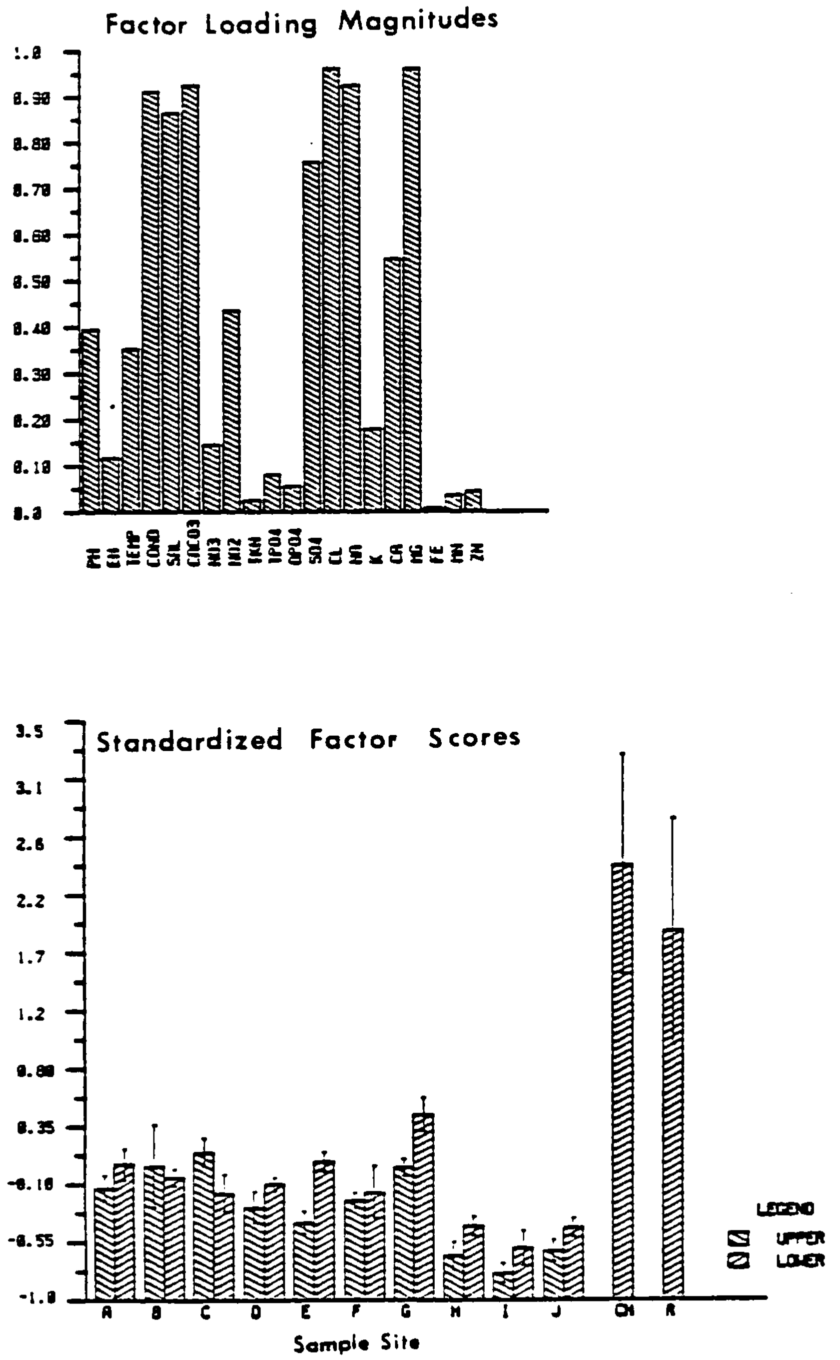


Figure 20. Bar graphs of factor loadings and score means by site for Factor 1, vertical lines represent 95% confidence ranges.

general increase in concentrations away from the river for the upper wells and decrease away from the river for the lower wells was present for many of the parameters listed earlier (hardness, sodium, chloride, and magnesium). The control wells (H, I, and J) all had the lowest mean scores among all sites.

Factor Two (Leachate Influence)

Factor two delineated those parameters most indicative of leachate from the landfill. Variables with the greatest magnitude along factor two were TKN, total phosphate, orthophosphate, and potassium. These four variables account for, approximately, 24% of the variance in the data.

Those sites expected to be influenced most by leachate (C_1 and G_2) had significantly higher mean scores (Figure 21). Score means for B_1 and G_2 were also, as expected, higher than the average.

Channel and river sites grouped with the other ground water sites, with mean site scores well below the total score mean. The large variance at B_1 is due to seasonality with summer samples (June-August) having much higher scores than the fall through spring scores.

TKN, total phosphate, orthophosphate and potassium are found in high concentrations in the leachate and in much lower concentrations in the surrounding ground and surface waters.

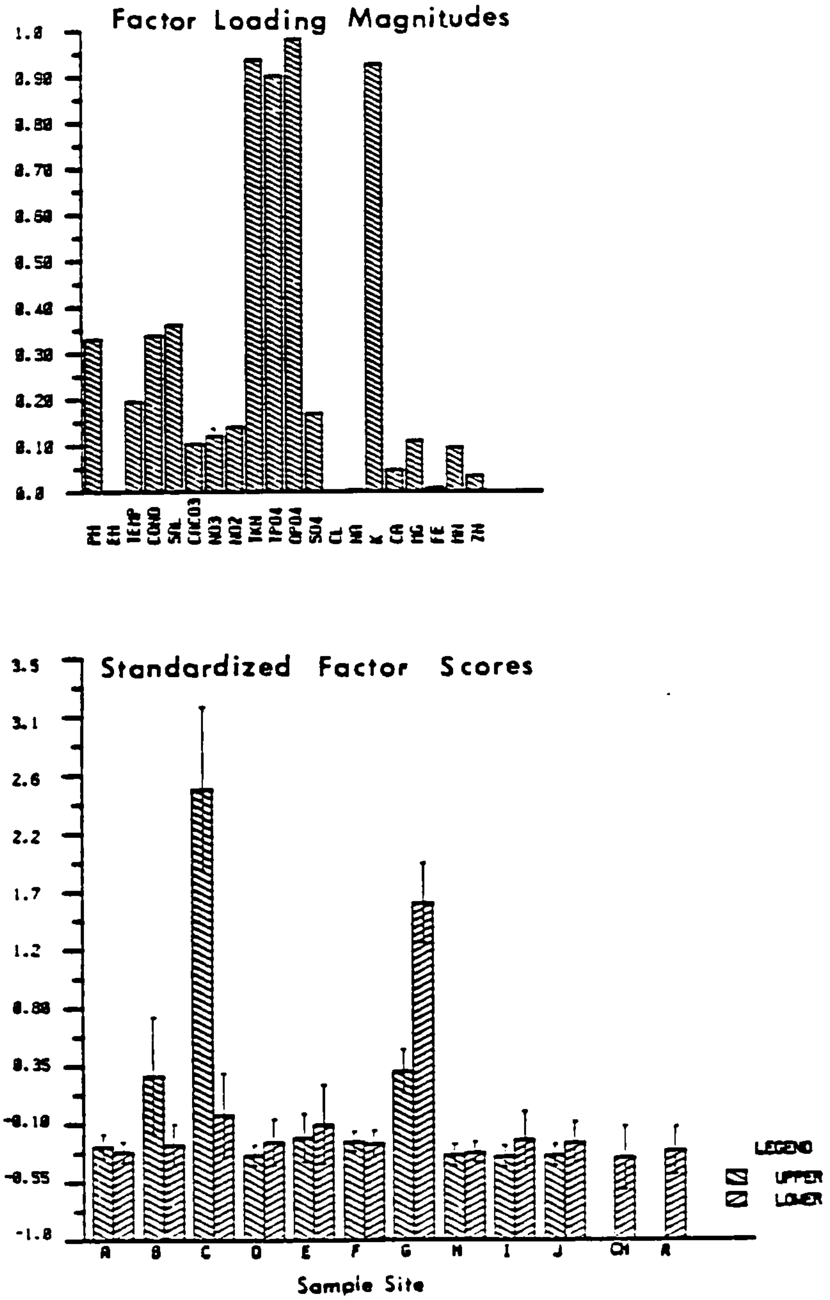


Figure 21. Bar graphs of factor loadings and score means by site for Factor 2, vertical lines represent 95% confidence ranges.

Factor Three (Sample Technique)

Factor three reflected a problem encountered in the first sampling period (9-2-82). A portion of the samples were field preserved with 1:1 HNO_3 for metal analysis. Several sites had a large amount of suspended particulates (especially F_2 and I_2), and consequently, the particulates were partially extracted by the acid. This resulted in anomalously high metal concentrations (particularly iron, manganese, and zinc) for the first sample period. For subsequent sampling, suspended material was removed by centrifugation prior to addition of the acid.

Since these anomalously high metal concentrations constituted a known source of error in the data, it was of interest to investigate how much variability was added by inclusion of the first sampling period. This would supply a qualitative estimate of the actual importance of other sources of variance. This source of error was later removed and the data re-analyzed with the principal factor technique.

The variables with high loadings for factor three were iron, manganese, zinc and to a lesser extent calcium and hardness (Figure 22). Sites F_2 and I_2 had, expectedly, very large variances due to the suspended sediment in the sample for the first date. Sites which typically had the least amount of sediment had the smallest variances.

Because this source of variance was due to sampling technique, analyses for the first date was removed from the data and factor analysis rerun. The result was to shift the

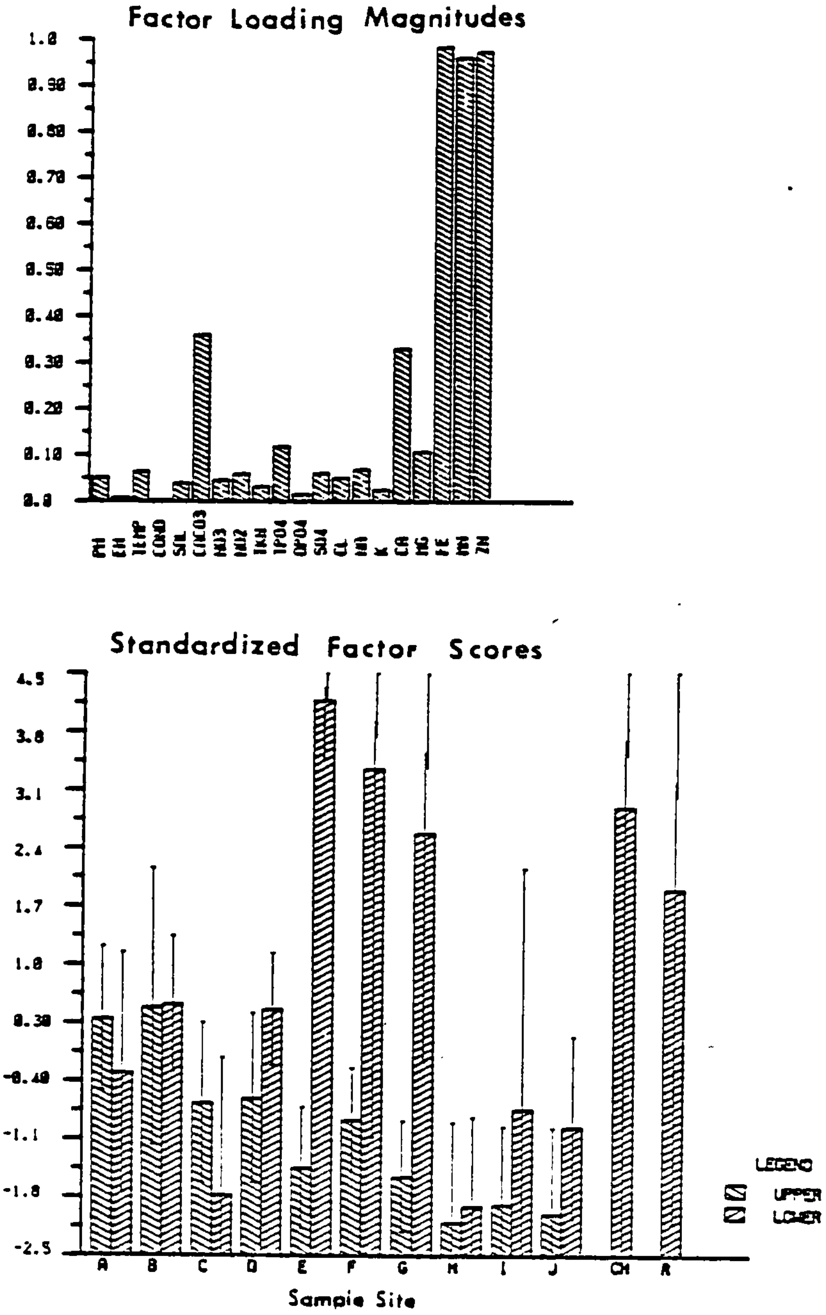


Figure 22. Bar graphs of factor loadings and score means by site for Factor 3, vertical lines represent 95% confidence ranges.

variance explained by factors four and five to factors three and four, with little change in factors one and two. With the removal of factor three, which accounted for 19% of the total variance, factors one and two increase in proportion of variance from 39% to 44% and 24% to 27% respectively. Factors four and five increased by less than 1% of total variance explained. The large increase in variance accounted for by factors 1 and 2 (13% for each factor) emphasizes the importance of these two factors over the remaining factor.

Factor Four (Site Depth)

Factor four accounted for 10% of the total variance and separated upper (3 meter) from lower (10 meter) wells. Eh, pH, temperature, and calcium had the largest magnitudes along this vector (Figure 23). Calcium and pH were negative loadings, indicating an inversely related trend between the original data and corresponding factor scores. In all cases, on a site by site basis, the upper well mean was greater than the lower well. However, this can only be considered a trend, as the difference between upper and lower wells was not significant for all sites. This trend suggests a general increase in pH and calcium and decrease in temperature and Eh (more reducing) with depth.

Factor Five (Remaining Variance)

Factor five accounted for the remainder of the variance in the data. Nitrate and nitrite were the principal sources

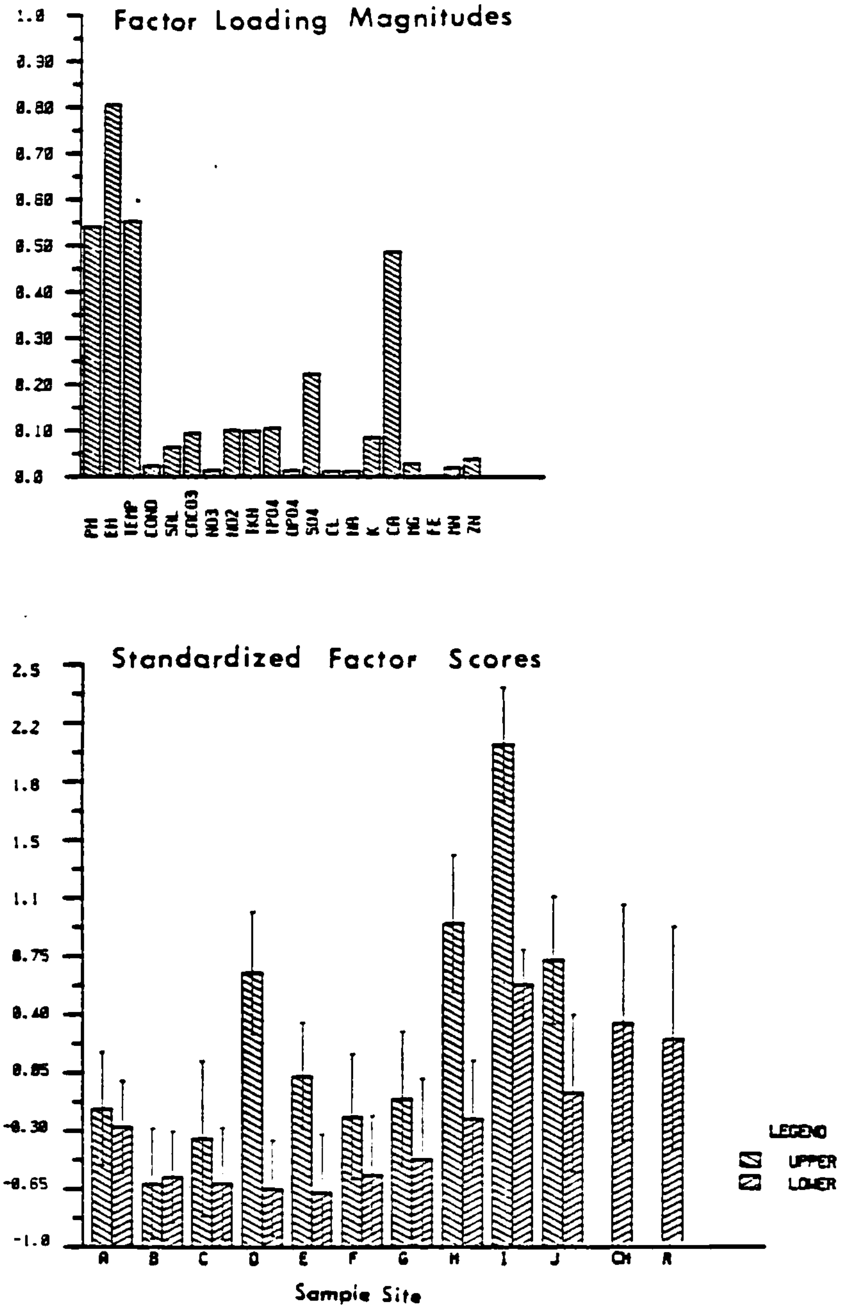


Figure 23. Bar graphs of factor loadings and score means by site for Factor 4, vertical lines represent 95% confidence ranges.

of variance, reflecting the lower means at sites D_2, E_2, F_2 and G_2. This factor also accounted for large amount of variance within surface water sites as well as sites A_2, B, C and J_1 for nitrate and nitrite (Figure 24).

The variance accounted for by factor five is relatively minor (8% of the total variance) and is not as well reflected by the original data as the other four factors. Therefore, only factors one through four (excluding three for sample handling error) accounted for geochemically interpretable variance. Factor five accounts for the remaining, relatively minor, variance in the data.

Factor Analysis Summary

Sixty-three percent of variance in the data was attributed to influence from surface water (39%) and leachate (24%). Conductivity, salinity, hardness, chloride, sodium, and magnesium had significantly higher concentrations in the surface water than ground water. These parameters were also present in elevated concentrations in the leachate. Leachate, however, was best characterized by high concentrations of TKN, total phosphate, orthophosphate, and potassium. TKN, phosphates, and potassium were present in much lower concentrations in the surface water and ground water. Calcium and pH increased with well depth due to an increase in shell material.

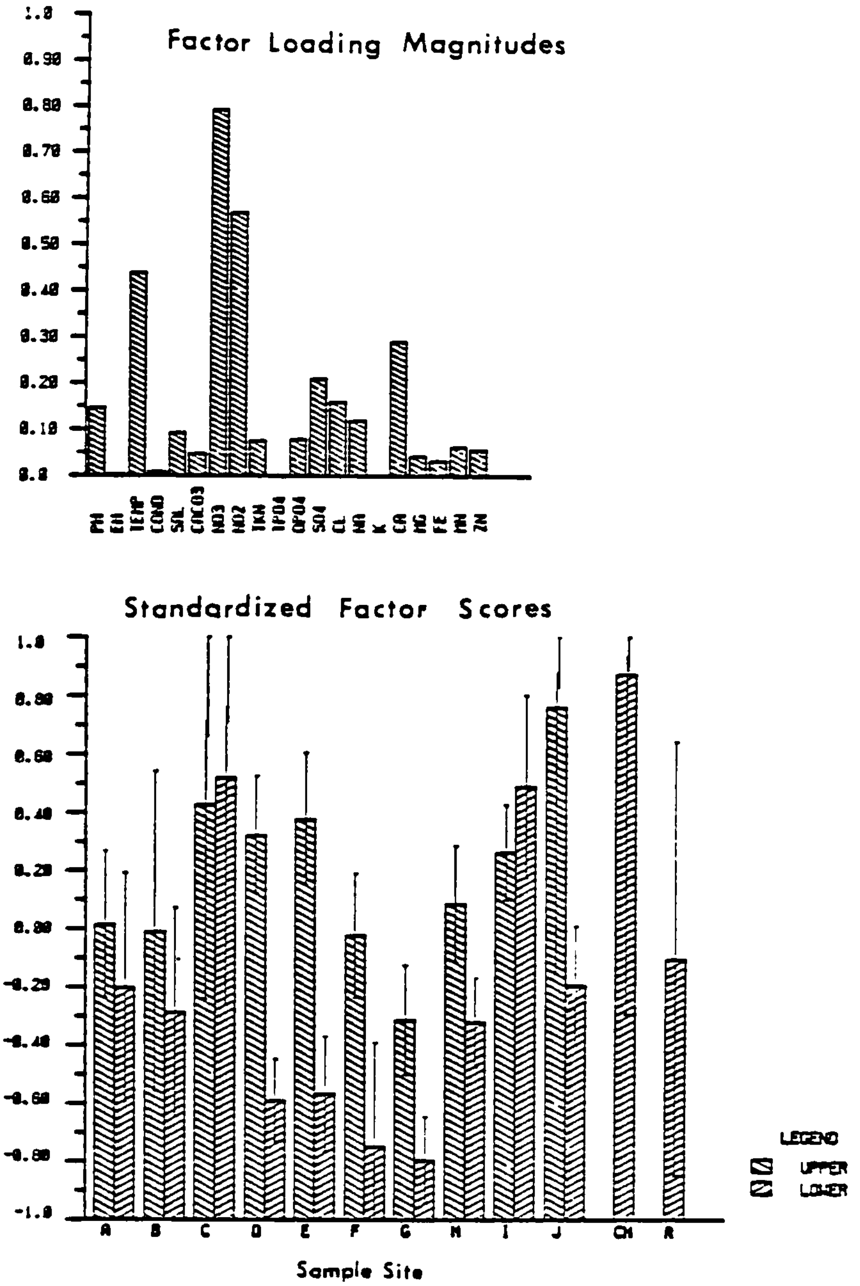


Figure 24. Bar graphs of factor loadings and score means by site for Factor 5, vertical lines represent 95% confidence ranges.

REGRESSION

Regression analysis was used to investigate the influence of tidal fluctuation, seasonal variation, depth, and horizontal distance on the parameters measured in this study. The model including all independent variables accounted for greater than 50% of the total variance for only a few dependent variables (Table 4). These were (in order of importance) chloride, sodium, magnesium, conductivity, temperature, hardness, calcium and salinity. Only chloride accounted for greater than 75% of the total variance.

Tidal fluctuation, independent of the other variables, accounted for less than 10% of the total variance for all dependent variables. Depth as the independent variable accounted for greater than 50% of total variance for chloride, sodium, and magnesium. Temperature was the only dependent variable which seasonal variation accounted for greater than 50% of the variance. Depth was the best estimator (regressor) for chloride, sodium, magnesium, conductivity, hardness and salinity; accounting for 70%, 62%, 54%, 45%, and 40% of the variance, respectively. Seasonal variation was the best estimator for temperature (55%) and horizontal distance for calcium (33%).

The variables best estimated by the independent (regressor) variables closely matched the variables with high loadings along factor one (surface water/groundwater). Only temperature and calcium did not have high loadings for

TABLE 4. Coefficient of determination (r^2) for five multiple regression models (depth, distance, seasonal, tidal, and total)

PARAMETER	DEPTH	DISTANCE	SEASONAL	TIDAL	TOTAL
pH	0.3038	0.2636	0.0039	0.0148	0.5730
Eh	0.0339	0.1614	0.1436	0.0071	0.3649
Conductivity	0.4644	0.3554	0.0289	0.0126	0.6435
Temperature	0.0497	0.0333	0.5512	0.0999	0.6403
Salinity	0.4447	0.3323	0.0142	0.0099	0.5649
Hardness	0.4033	0.3392	0.0136	0.0257	0.6245
Nitrate	0.0495	0.0736	0.0080	0.0012	0.0895
Nitrite	0.2544	0.1908	0.0302	0.0369	0.3236
TKN	0.3285	0.2629	0.0423	0.0122	0.3285
Total Phosphate	0.0125	0.2099	0.0354	0.0001	0.2695
Orthophosphate	0.0276	0.2676	0.0158	0.0110	0.3131
Sulfate	0.4630	0.3073	0.0054	0.0101	0.4772
Chloride	0.6966	0.4742	0.0225	0.0066	0.7622
Sodium	0.6150	0.4297	0.0115	0.0090	0.6787
Potassium	0.0284	0.3051	0.0096	0.0063	0.3758
Calcium	0.2721	0.3255	0.0093	0.0221	0.5816
Magnesium	0.5369	0.3616	0.0059	0.0198	0.6446
Iron	0.0108	0.0060	0.0349	0.0058	0.0532
Manganese	0.0107	0.0207	0.0207	0.0113	0.0524
Zinc	0.0223	0.0104	0.0205	0.0009	0.0569
Factor 1	0.6104	0.4326	0.0191	0.0290	0.7265
Factor 2	0.0405	0.3328	0.0066	0.0025	0.3738
Factor 3	0.1933	0.1422	0.2183	0.0172	0.5888
Factor 4	0.1284	0.2766	0.0095	0.0111	0.3845
Factor 5	0.1531	0.0878	0.0682	0.0104	0.2676

factor one. All the variables with high factor loadings (conductivity, salinity, hardness, sulfate, chloride, sodium, and magnesium) were most dependent on depth as a regressor variable(s). Since the three depths possible were surface water, 3 meter wells, and 10 meter wells, this dependency was not surprising.

As a check for this observed relationship between the dummy variables for depth and high loadings along factor one, all independent variables together, as well as separately, were regressed against the factor scores for factors one and two. The independent variables together accounted for 73% of the variance in factor one, with depth responsible for 61% of the variance. For factor two (leachate/groundwater-surface water), 37% of the variance was accounted for by the regressor variables. Horizontal distance was responsible for 33% of the variance in factor two scores. Variables with high loadings along factor two (TKN, TPO_4, OPO_4 and K) were influenced most by horizontal distance. With the greatest decrease in leachate concentration occuring horizontally between the landfill and river (transect A-C), the relationship between factor two scores and horizontal distance was expected.

The independent variable of particular interest in this regression analysis (tidal fluctuation) was neither statistically or geochemically significant. To further investigate possible tidal influence on the groundwater geochemistry, conductivities and water levels were measured hourly along transect A-C for one complete tidal cycle. There was a slight correlation between conductivity and water level for the upper wells, and no correlation for the lower wells. At site A (adjacent to the river), the upper well (A_1) had a correlation of 0.63 and the lower well (A_2) had a correlation of 0.05 (Figure 25). Conductivity correlated with water level at 0.48 for well C_1 and at <0.01 for well C_2. The slight correlation for the upper wells (A_1 and C_1) suggests there may be some minimal influence from tidal fluctuation. When conductivity was correlated with tidal level over the entire year at A_1, there was no significant inter-relationship ($r=0.03$). Although tidal fluctuation has no significant long term impact on the parameters measured, correlation between conductivity and water level at well A_1 is additional evidence that may be some intrusion of brackish water from the river.

SUMMARY AND RECOMMENDATIONS

The Chesapeake landfill appears to be typical of many municipal landfills in coastal plain and other low-lying areas. The landfill is located in, and bounded to the north and west by a tidal marsh. The Chesapeake landfill first began operation in the mid to late sixties, and is therefore a relatively old (mature) landfill. The original mode of operation was to trench and dewater while the trash was deposited and compacted. Presently, refuse is being redeposited over the oldest portion of the landfill

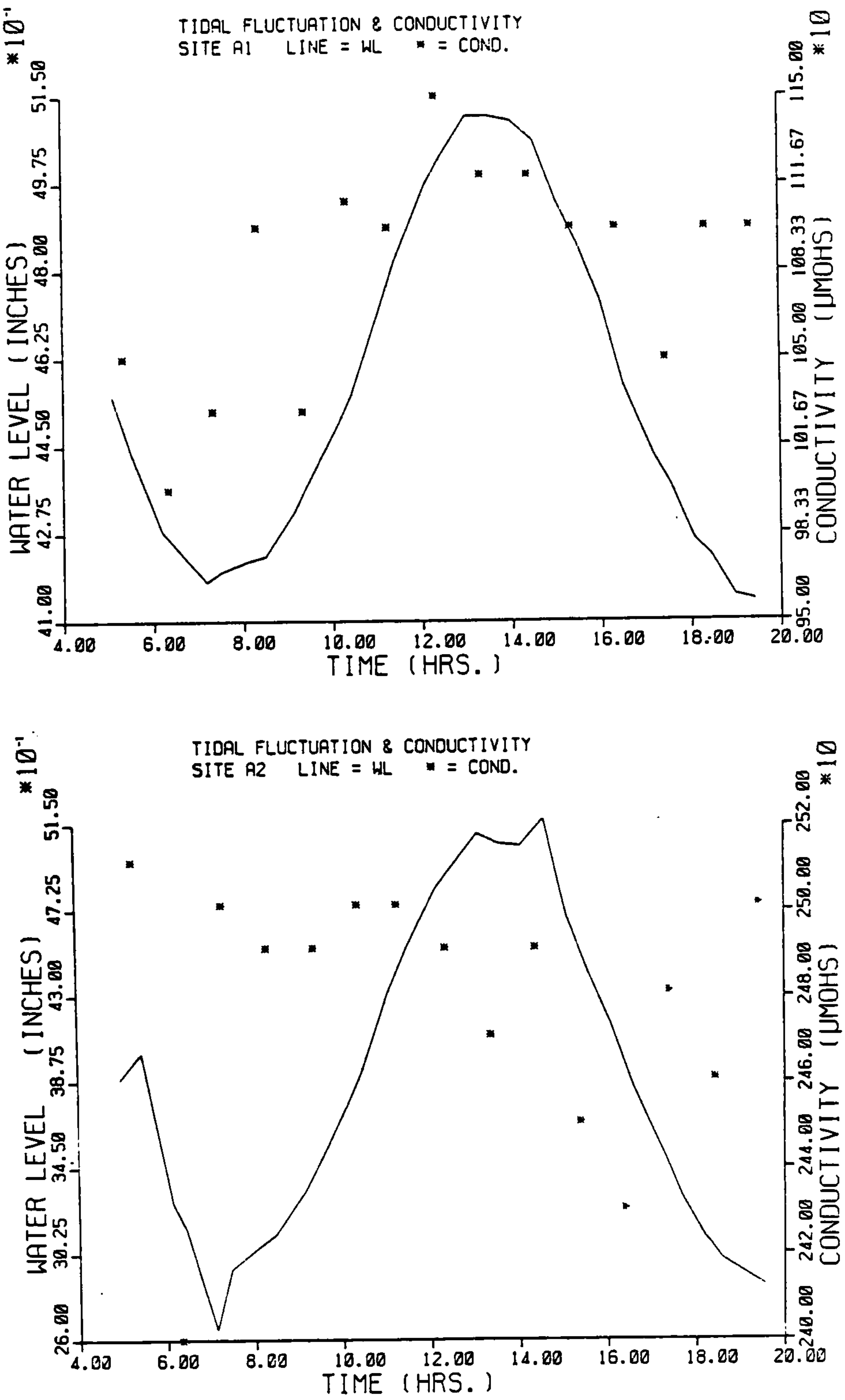


Figure 25. Graphs of tidal fluctuation and conductivity with time for wells A1 and A2.

(eastern edge), extending as far west as transect A-C (Figure 5, p. 12).

The water table is high in this area, as evidenced by the adjacent marsh, and the landfill's base is in a medium to fine sand which underlies the marsh clay. Since no liner, clay or otherwise, was initially used, it would be safe to assume the landfill is at least partially saturated with groundwater. Cover for the landfill is of local material and usually sandy in nature. The refuse is primarily from residential and small industrial sources, with the largest industrial input being wood and wood by-products. With no real physical impediment for leachate flow from the landfill, the low hydraulic gradient would be the primary restrictor of leachate movement. The leachate plume is concentrated north of the landfill, centered arount transect A-C and paralleling the hydrologic head distribution (Figure 8). Leachate found to the west, at site G, is due to the close proximity of the surface water (which abuts the landfill at high tide). Net flow of groundwater around site G is probably west. Any detrimental effect from leachate on the surrounding ground and surface waters would be from nutrient enrichment of the adjacent marsh and waterway. It has been suggested, however, that the marsh may serve as both a nutrient source and sink, especially for nitrogen and phosphorus (Heinel and Flemer, 1976; Valeela et al., 1978; Wolaver et al., 1983; Wolaver and Zieman, 1984). If this is true, the leachate may have little detrimental influence on the adjacent surface water. Interaction of leachate with the marshland deserves further study.

The source of variance in many parameters measured in this study was traced back to either surface water or leachate influence. Higher concentrations for hardness, sodium, chloride, magnesium, and sulfate, as well as, high conductivity and salinity was indicative of the surface water. These seven variables (except sulfate) were also present in high concentrations in the leachate, relative to the ambient groundwater. Well sites adjacent to the surface water had elevated concentrations for hardness, sulfate, sodium, chloride, and magnesium. This is probably due to some recharge from the river.

Total kjeldahl nitrogen, phosphate (total and ortho), and leachate than ambient groundwater and surface water. Concentrations for these parameters did not differ significantly between the ground and surface water.

Organic nitrogen and phosphates are very common by-products of biochemical-chemical degredation of municipal refuse. They possess qualities desirable for a good leachate indicator (high concentration in the leachate and mobile). However, because of interferences with the analysis of phosphates and nitrogen, a great deal of care must be taken in the labratory procedures. Total kjeldhal nitrogen was particularly difficult to measure.

Potassium, on the other hand, is also present in leachate in high concentrations and is relatively mobile with few, and minor, interferences. The ease in preservation and long holding time makes potassium additionally attractive as a leachate indicator. It also is a common by-product of organic waste degredation and has been recognized as a primary constituent of leachate, especially during generation and stabilization of the fill (Chain and De Walle, 1975; Johansen and Carlson, 1976; Fenn et al., 1977; Ellis, 1979; Lu et al., 1981; Tredoux, 1984).

Temperature, Eh, pH, and calcium varied most with depth. Temperature decreased and Eh became more reducing while calcium and pH increased with depth. The decrease in temperature and Eh with depth follows the expected natural trend for a water table aquifer. The increase in calcium and pH was due, at least in part, to an increase in calcareous shell material with depth.

While tidal fluctuation had no observable influence on the groundwater geochemistry, there did appear to be a significant seasonal influence for most parameters measured. Salinity, conductivity, pH, total kjeldhal nitrogen, total and orthophosphate, chloride, sodium, potassium, calcium, and magnesium increased sharply during the summer months for site B_1 (midway between the landfill and river). Ideally the wells should be monitored monthly for the summers (June through August) and seasonally for the remaining year (fall, winter, and spring) in order to establish the exact affect of seasonal change on leachate variability. A rain gauge should be installed to monitor local precipitation, and evapotranspiration estimated for water budget approximations. In order to accurately predict seasonal influence, monitoring would have to take place over several complete seasonal cycles. Parameters recommended for measurement in such a study are pH, conductivity, orthophosphate, sodium (or chloride), potassium, and calcium.

CONCLUSIONS

Variation in most parameters measured in this study was due to either leachate influence or surface water influence. Leachate was characterized best by significantly higher concentrations of potassium, total phosphate, orthophosphate, and total kjeldahl nitrogen over the ambient groundwater and surface water. Conductivity, salinity, hardness, sodium, chloride, and magnesium were also present in leachate at significantly higher levels than the ambient groundwater. Although higher pH and calcium values were also indicatative of leachate, the major source of variance for these parameters was apparently due to an increase in calcareous shell material with depth.

Parameters found in significantly higher levels in the surface water over leachate and groundwater were conductivity, salinity, hardness, sodium, chloride, magnesium, and sulfate. Groundwater samples taken adjacent to the surface water had elevated concentrations for hardness, sulfate, sodium, chloride, and magnesium. This is most likely due to intrusion of brackish water from the river.

Because of influence from sources other than landfill leachate, parameters traditionally used for routinely monitoring leachate (pH, chloride, and conductivity) are not appropriate for sites in, or adjacent to naturally brackish water. Potassium appears to be the most promising parameter for routine monitoring in coastal marshlands and estuaries, in that it is:

1) present in leachate in much higher concentrations than the ambient groundwater
2) easily stored, preserved, and analyzed
3) relatively free of interferences

Total phosphate and orthophosphate are also good candidates for use in routine monitoring, although greater care must be taken to correct for interferences for these analyses. TKN, though present in much higher levels in the leachate, is too time consuming to measure to be used routinely.

Tidal fluctuation had no apparent influence on the groundwater geochemistry. Seasonal variation, however, did affect salinity, conductivity, pH, total kjeldhal nitrogen, potassium, calcium, and magnesium at site B_1 (midway between the landfill and river). These parameters increased significantly during the summer months (July through August). Additional monitoring is required to accurately evaluate the effect of seasonal variation on the leachate. Lateral variation in groundwater mounding under the landfill and heterogeneity in grain size distribution in the aquifer significantly influenced the position of the leachate plume over a short areal distance. This emphasizes the need for a rigourous hydrologic evaluation of the aquifer in contact with the landfill before installation of wells for routine monitoring.

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Appendix A. Well logs taken from wash borings and measured water levels for all well sites.

SITE A

Depth	Description
0-7'	dredge spoil, poorly sorted white sand
8'	organic clay (thin layer)
8-28'	medium to fine lt. gray sand
28-31'	fine gray sand, with increasing shell fragments
31'	clay

SITE B

Depth	Description
0-6'	dredge spoil, poorly sorted white sand
8-9'	organic clay
9-25'	medium to fine gray sand
25-30'	medium gray sand, increasing shell fragments

SITE C

Depth	Description
0-10'	dredge spoil, rust colored, poorly sorted sand
10-11'	organic clay
11'	lt. gray clay
11-20'	medium to fine lt. gray sand
20-23'	clay ? (no sample taken)
23-29'	medium to fine gray sand with increase in shell fragment

SITE D

Depth	Description
0-3'	dredge spoil, poorly sorted white sand
3-5'	organic clay
5-6'	lt. gray clay
6-30'	medium to fine gray sand

SITE E

Depth	Description
0-2'	dredge spoil, poorly sorted white sand
2-6'	organic clay
6-28'	medium to fine gray sand with increase in shell fragments

SITE F

Depth	Description
0-8'	dredge spoil, poorly sorted rust to dark red stained sand
8-11'	organic clay
11-18'	medium lt. gray sand
18-20'	clay ? (no sample taken)
20-29'	medium to fine gray sand

SITE G

Depth	Description
0-4'	organic clay
5-6'	lt. gray clay
8-20'	medium to fine gray sand
20'	clay

SITE H

Depth	Description
0-7'	loamy soil
7-10'	clean fine white sand
10-20'	fine gray sand
20-30'	fine gray sand with shell fragments
30-33'	medium to fine gray sand with increasing shell fragments
33'	clay

SITE I

Depth	Description
0-8'	loamy soil
8-20'	lt. brown to red, medium to fine sand
20-25'	dk. brown to gray, medium to fine sand
25'	dk. gray clay

SITE J

Depth	Description
0-3'	sandy loam soil
3-10'	lt. gray to white medium sand
10-13'	lt. gray to brown medium sand
13-18'	dk brown to gray medium sand
18'	clay

CONDUCTIVITIES AND WATER LEVELS MEASURED HOURLY TO SEMIHOURLY FOR WELL SITESD A AND C, OCTOBER 6-7, 1982

WELL SITE A

Conductivity (uMOH)

Time	Well 1	Well 2
1720	1050	2510
1820	1000	2400
1920	1030	2500
2020	1100	2490
2120	1030	2490
2220	1110	2500
2320	1100	2500
2420	1150	2490
0120	1120	2470
0220	1120	2490
0320	1100	2450
0420	1100	2430
0520	1050	2480
0620	1100	2460
0720	1100	2500

Water Levels (in)

Time	Well 1	Time	Well 2
1706	4.55	1703	3.87
1730	4.44	1732	4.00
1812	4.28	1713	3.27
1830	4.25	1831	3.14
1910	4.18	1911	2.65
1930	4.20	1931	2.95
2005	4.22	2006	3.05
2030	4.23	2032	3.12
2109	4.32	2112	3.33
2129	4.38	2130	3.46
2207	4.49	2209	3.75
2226	4.55	2227	3.90
2301	4.71	2303	4.29
2325	4.82	2327	4.50
2406	4.97	2408	4.80
2428	5.03	2430	4.91
0102	5.11	0104	5.07
0130	5.11	0131	5.02
0201	5.10	0202	5.01
0231	5.06	0233	5.14
0301	4.94	0303	4.66
0330	4.85	0331	4.39
0400	4.74	0401	4.14

WELL SITE C

Conductivity (uMOH)

Time	Well 1	Well 2
0815	3800	5100
0910	3890	5200
1015	3900	5300
1115	3900	5500
1205	3890	5200
1310	3900	5100
1410	3880	5100
1510	4650	5100
1605	4220	5100
1710	4130	5100
1810	3950	5100
1915	3980	5100
2010	4000	5100
2115	4150	5100
2215	3910	5100

Water Levels (in)

Time	Well 1	Time	Well 2
0806	6.35	0807	3.03
0835	6.33	0838	3.06
0908	6.33	0907	3.18
0935	6.30	0935	3.34
1012	6.32	1015	3.58
1035	6.31	1037	3.82
1108	6.32	1109	4.13
1132	6.35	1133	4.36
1201	6.32	1202	4.62
1233	6.34	1235	4.86
1305	6.36	1306	5.07
1336	6.41	1337	5.19
1406	6.42	1407	5.24
1433	6.41	1434	5.20
1505	6.44	1506	5.10
1535	6.45	1537	4.93
1603	6.45	1604	4.77
1634	6.47	1635	4.53
1708	6.43	1709	4.27
1736	6.44	1737	4.06
1805	6.42	1806	3.79
1835	6.43	1836	3.54
1911	6.43	1912	3.34

Water Levels (in) (Cont'd)

Time	Well 1	Time	Well 2
0430	4.57	0431	3.83
0510	4.43	0513	3.49
0533	4.37	0536	3.29
0605	4.26	0606	3.10
0626	4.23	0628	2.99
0658	4.15	0659	2.92
0724	4.14	0725	2.86

Water Levels (in) (Cont'd)

Time	Well 1	Time	Well 2
1935	6.43	1937	3.10
2006	6.40	2007	3.05
2035	6.40	2036	3.05
2108	6.38	2110	3.09
2138	6.39	2140	3.20
2211	6.36	2212	3.29
2235	6.36	2226	3.41

WATER LEVELS MEASURED FOR ALL WELL SITES

OCTOBER 23, 1982

Well	Water Level (ft)	Well	Water Level (ft)
A1	5.69	A2	5.43
B1	6.02	B2	5.51
C1	7.07	C2	5.41
D1	5.70	D2	5.55
E1	5.96	E2	4.42
F1	6.03	F2	5.67
G1	5.99	G2	5.88
H1	5.14	H2	4.28
I1	7.39	I2	2.57
J1	6.19	J2	6.45

Appendix B. Data from previous research, Chesapeake Landfill.

CHESAPEAKE LANDFILL DATA
(Rule, 1979)

NON-METAL PARAMETERS
(July, 1978)

Station	pH	Eh(mv)	Cl$^-$(mg/l)
1	6.6	+194	17
2	6.8	+364	4600
3	7.0	+384	410
4	7.2	+394	4100

NON-METAL PARAMETERS
(August, 1978)

				Solids(mg/l)		Coliforms	
Station	pH	Eh(mv)	Cl$^-$(mg/l)	T.S.	T.D.S.	Total	Fecal
1	6.1	+214	10	220	202	>8000	190
2	7.0	+304	6400	11,574	11,494	>8000	120
3	7.0	+304	780	1,996	2,006	20	20
4	7.2	+374	6200	10,902	10,906	>8000	740
5	7.0	+304	7200	13,502	13,482	>8000	160
6	7.1	+234	34	332	—	0	0
7	7.2	+344	32	335	—	1	0
8	7.2	+314	9700	16,400	16,396	>8000	970

CHESAPEAKE LANDFILL DATA
(Rule, 1979)

METAL CONCENTRATIONS (mg/l)
(July, 1978)

	Cd		Cr		Cu		Ni		Pb		Zn	
Station	T*	D**	T	D	T	D	T	D	T	D	T	D
1	.006	.001	.05	.05	.014	<.001	.005	.005	.020	<.005	20	17
2	<.001	.001	.05	.05	.006	<.001	.005	.005	<.005	<.005	.04	.01
3	.002	.001	.05	.05	.013	.001	.005	.005	.056	.017	30	10
4	.001	.001	.05	.05	.007	<.001	.005	.005	<.005	<.005	.04	.02

METAL CONCENTRATIONS (mg/l)
(August, 1978)

	Cd		Cr		Cu		Ni		Pb		Zn	
Station	T*	D**	T	D	T	D	T	D	T	D	T	D
1	.004	.001	.05	.05	.011	.005	.005	.005	.005	.005	20	18
2	.002	.001	.05	.05	.004	.001	.005	.005	.005	.005	.02	.01
3	.003	.001	.05	.05	.006	.003	.005	.005	.005	.005	5.0	4.0
4	<.001	.001	.05	.05	.003	<.001	.005	.005	.005	.005	.02	.01
5	.001	.001	.05	.05	.003	<.001	.005	.005	.005	.005	.03	.02
6	<.001	—	.05	—	.015	—	.005	.005	.005	—	.01	—
7	<.001	—	.05	—	.026	—	.005	.005	.005	—	.005	—
8	<.001	.001	.05	.05	.003	<.001	.005	.005	.005	.005	.02	.01

CHESAPEAKE LANDFILL DATA
(McMillan, Preliminary Research)

Site	3/18/81	3/21/81	4/18/81	5/24/81	7/13/81
pH					
A-1	6.2	6.3	6.4	6.6	6.50
B-1	6.8	NS	6.5	6.6	6.45
C-1	6.6	7.0	7.1	7.0	6.85
D-1	6.6	NR	6.9	7.1	6.80
A-2	6.8	6.85	6.3	6.3	6.20
B-2	6.6	6.45	6.2	6.4	6.50
C-2	6.6	6.65	6.6	6.7	6.65
D-2	NS	NS	7.1	NS	NS
Eh (mv)					
A-1	NR	-165	-190	-190	-200
B-1	-140	NS	-200	-180	-212
C-1	NR	-60	-50	-48	-15
D-1	+0	NR	+60	+32	+98
A-2	+170	+60	+80	-125	-40
B-2	NR	+120	+20	-80	-50
C-2	-195	NR	-250	-230	-240
D-2	NS	NS	-140	NS	NS
Conductivity (MOHS)					
A-1	NR	NR	NR	1480	1520
B-1	NR	NR	NR	1650	181
C-1	NR	NR	NR	550	51
D-1	NR	NR	NR	1820	1720
A-2	NR	NR	NR	550	380
B-2	NR	NR	NR	980	380
C-2	NR	NR	NR	2230	2490
D-2	NR	NR	NR	NS	NS

*NS = No Sample
**NR = No Reading

CHESAPEAKE LANDFILL DATA
(McMillan, Preliminary Research)

Site	3/18/81	3/21/81	4/18/81	5/24/81	7/13/81
	Salinity (^{o}/oo)				
A-1	NR	NR	NR	1.0	0.8
B-1	NR	NR	NR	1.0	1.0
C-1	NR	NR	NR	0.5	0.0
D-1	NR	NR	NR	1.0	1.0
A-2	NR	NR	NR	0.1	0.0
B-2	NR	NR	NR	0.5	0.3
C-2	NR	NR	NR	1.5	1.8
D-2	NR	NR	NR	NS	NS
	NO_2 (mg/l)				
A-1	NS	BLD	BLD	2.76	2.0
B-1	NS	NS	BLD	2.59	2.0
C-1	NS	BLD	0.57	2.76	2.0
D-1	221.0	25.9	582.6	258	393-332
A-2	NS	BLD	BLD	BLD	2.0
B-2	BLD	BLD	4.57	7.14	7.18
C-2	BLD	BLD	BLD	BLD	2.0
D-2	NS	NS	BLD	NS	NS
	TKN (mg/l)				
A-1	4.5	8.8	6.6	1.3	over
B-1	3.1	NS	NS	NS	over
C-1	1.4	2.7	1.7	0.9	1.23
D-1	NR	14.0	11.8	1.4	0.0
A-2	2.58	5.6	3.5	1.5	over
B-2	3.44	2.4	2.6	0.8	1.62
C-2	+10 (over)	over	23.2	0.8	1.18
D-2	NS	NS	6.2	NS	NS

*NS = No Sample
**NR = No Reading

CHESAPEAKE LANDFILL DATA
(McMillan, Preliminary Research)

Site	3/18/81	3/21/81	4/18/81	5/24/81	7/13/81
PO_4 (mg/l)					
A-1	NS*	1.04	0.968	1.22	0.98
B-1	NS	NS	0.000	NS	0.91
C-1	NS	0.01	0.000	0.02	BLD
D-1	0.021	0.030	0.020	0.10	0.02
A-2	NS	0.02	0.035	0.05	BLD
B-2	0.009	0.010	0.000	0.02	BLD
C-2	0.000	0.000	0.000	0.03	BLD
D-2	NS	NS	NS	NS	NS
SO_4 (mg/l)					
A-1	NR	3.0	NR	NR	NR
B-1	NR	NS	NR	NR	NR
C-1	NR	11.0	NR	NR	NR
D-1	NR	over	NR	NR	NR
A-2	NR	34.8	NR	NR	NR
B-2	NR	over	NR	NR	NR
C-2	NR	26.2	NR	NR	NR
D-2	NR	NS	NR	NR	NR
Na (mg/l)					
A-1	NS	57.9	57.0	282.0	299.9
B-1	NS	NS	NS	364.0	369.0
C-1	2.4	2.5	1.7	17.0	9.1
D-1	10.8	11.4	11.5	46.7	38.1
A-2	45.6	37.7	23.3	88.2	54.6
B-2	64.8	41.5	23.0	91.7	81.9
C-2	54.4	49.9	45.3	212.0	218.0
D-2	NS	NS	NS	NS	NS

*NS = No Sample
**NR = No Reading

CHESAPEAKE LANDFILL DATA
(McMillan, Prliminary Research)

Site	3/18/81	3/21/81	4/18/81	5/24/81	7/13/81
Cl (mg/l)					
A-1	NS	520	NR	415	435
B-1	NS	NS	NR	450	505
C-1	NS	84	NR	BLD	BLD
D-1	210	220	NR	205	120
A-2	NS	210	NR	140	105
B-2	720	390	NR	218	150
C-2	940	840	NR	525	560
D-2	NS	NS	NR	NS	NS
K (mg/l)					
A-1	NS	15.4	15.4	16.74	17.65
B-1	NS	NS	NS	13.42	13.99
C-1	109.9	113.0	79.5	72.60	42.90
D-1	204.5	195.3	216.7	182.20	157.10
A-2	8.3	7.3	10.3	12.85	11.94
B-2	15.4	16.4	33.7	41.70	41.70
C-2	235.0	211.6	162.8	174.20	191.30
D-2	NS	NS	NS	NS	NS
Ca (mg/l)					
A-1	NS	28.1	24.9	24.88	24.02
B-1	NS	NS	NS	46.51	47.38
C-1	77.4	80.4	65.5	55.60	58.50
D-1	427.0	415.0	370.0	231.50	225.80
A-2	24.1	18.1	21.1	16.52	84.40
B-2	160.4	130.7	80.4	64.20	52.70
C-2	296.7	246.3	190.0	188.30	196.90
D-2	NS	NS	NS	NS	NS

*NS - No Sample
**NR - No Reading

CHESAPEAKE LANDFILL DATA
(McMillan, Preliminary Research)

Site	3/18/81	3/21/81	4/18/81	5/24/81	7/13/81
Mg (mg/l)					
A-1	NS*	31.1	30.9	29.7	29.7
B-1	NS	NS	NS	32.9	32.3
C-1	8.6	9.4	6.9	6.2	6.2
D-1	30.9	35.5	32.6	27.9	25.0
A-2	15.9	14.2	14.2	13.7	5.9
B-2	over	over	over	56.9	47.9
C-2	53.5	50.1	41.8	42.5	44.2
D-2	NS	NS	NS	NS	NS
Fe (mg/l)					
A-1	NS	30.0	24.1	NR**	NR
B-1	NS	NS	NS	NR	NR
C-1	77.4	80.4	65.5	NR	NR
D-1	427.0	415.2	370.7	NR	NR
A-2	24.1	18.1	21.1	NR	NR
B-2	160.4	130.7	80.4	NR	NR
C-2	296.7	246.3	190.0	NR	NR
D-2	NS	NS	NS	NR	NR

*NS = No Sample
**NR = No Reading

Appendix C. Total data set for all parameters and samples sites, Chesapeake Landfill.

pH

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	6.15	6.45	6.20	6.35	6.20	6.40	6.05	6.40	6.50	6.30	6.30	6.10
B_1	6.90	6.50	6.20	6.40	6.30	6.35	6.30	6.90	7.10	7.00	7.00	6.45
C_1	7.20	7.00	6.35	7.10	6.90	7.10	7.05	7.05	7.00	7.05	7.05	6.85
D_1	5.70	5.95	6.75	5.60	5.30	5.85	6.10	5.55	5.85	5.80	5.40	5.40
E_1	5.85	6.00	5.50	6.20	5.85	6.15	5.20	6.00	6.10	5.95	5.80	6.10
F_1	*ND	6.40	5.70	6.25	6.00	6.35	6.50	6.20	6.35	6.15	6.15	6.10
G_1	7.15	6.80	5.90	6.90	6.65	6.80	6.90	6.70	6.75	6.60	6.60	6.95
H_1	5.60	6.00	7.20	6.65	5.40	5.90	5.00	5.50	5.20	5.75	5.50	5.50
I_1	4.70	5.15	5.60	5.00	4.80	5.40	5.10	5.05	5.05	5.20	4.85	5.60
J_1	5.85	6.10	4.90	6.00	5.80	6.30	5.85	5.90	6.10	6.20	5.80	5.90
A_2	6.68	6.80	6.00	6.70	*ND	6.90	6.35	6.80	6.85	6.80	6.80	6.55
B_2	6.58	6.85	*ND	6.80	6.70	6.95	6.65	6.75	6.90	6.85	6.85	6.66
C_2	7.09	6.95	6.60	7.20	7.10	7.10	7.15	7.00	7.20	7.05	6.90	7.00
D_2	7.05	7.00	6.70	6.90	6.90	7.30	6.90	6.90	7.00	6.80	6.90	6.70
E_2	6.90	*ND	6.65	7.00	6.65	6.90	6.85	6.60	6.70	6.45	6.45	6.45
F_2	6.47	6.75	6.80	6.70	6.65	7.00	6.85	6.85	6.90	6.70	6.70	6.40
G_2	7.10	7.10	7.25	7.10	6.95	7.10	7.15	6.95	6.95	6.95	6.80	7.30
H_2	6.25	6.90	7.00	7.20	7.10	7.05	6.40	7.00	6.80	7.25	6.90	6.40
I_2	5.50	*ND	5.80	6.10	5.80	6.70	5.70	5.85	6.40	6.35	5.85	5.70
J_2	6.60	6.95	6.60	6.75	6.70	6.95	6.40	6.80	6.55	7.00	6.65	6.40
Ch	*ND	6.65	6.85	6.85	6.75	6.80	7.45	7.10	6.70	6.80	6.65	7.05
R	*ND	*ND	*ND	6.60	6.80	6.90	7.15	6.40	6.85	6.80	6.70	7.10

*ND = No Data

Eh (mv)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	-150	-25	-130	-190	-130	-90	-90	-10	65	-70	-35	-55
B_1	-180	-55	-70	-160	-130	-80	-85	-20	60	-200	-160	-40
C_1	30	-50	-80	-160	-140	-30	-60	50	60	-155	-60	-60
D_1	-35	0	-65	-80	-60	-140	-80	110	-10	-30	-40	-90
E1	-40	-100	-110	-170	-165	-180	-170	70	-60	-115	-90	-110
F_1	*ND	-130	-120	-190	-190	-200	-170	-10	-20	-100	-55	-110
G_1	-75	-70	-20	-110	-40	-30	-100	40	150	-100	10	65
H_1	-15	-20	-30	-70	-60	-60	-70	90	130	45	-30	-15
I_1	120	90	110	10	30	70	10	180	255	90	55	70
J_1	10	0	15	-80	-70	-80	-80	65	190	50	-20	10
A_2	-40	-50	*ND	-120	*ND	-110	-70	20	75	-70	-40	-40
B_2	-110	-60	-40	-130	-110	50	-80	10	40	-140	-60	-60
C_2	-20	-60	-80	-120	-150	-130	-80	35	50	-160	-30	-55
D_2	-90	-70	-40	-110	-90	-160	-80	30	-10	-90	-60	-30
E_2	-65	*ND	-70	-120	-170	-100	-130	10	-30	-120	-60	-100
F_2	-95	-60	0	-110	-170	70	-120	10	-30	-110	-34	-100
G_2	-30	-40	-70	-110	-100	-210	-100	35	110	-100	10	50
H_2	-30	-50	-80	-100	-70	60	-80	100	130	-10	-80	-40
I_2	25	*ND	-50	-90	10	60	-10	120	40	30	-40	-50
J_2	-60	-30	-50	-110	-100	-90	-90	220	210	20	-120	-70
Ch	*ND	-45	20	-50	-40	-100	-80	65	180	-10	40	100
R	*ND	*ND	*ND	-170	-50	65	-50	80	120	10	150	100

*ND = No Data

TEMPERATURE (°C)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	*ND	*ND	16.0	*ND	10.0	12.0	12.0	16.5	19.5	19.0	20.0	19.0
B_1	*ND	*ND	16.5	*ND	9.0	9.5	12.0	16.0	23.0	19.0	10.0	17.0
C_1	*ND	*ND	15.0	*ND	12.0	12.5	13.5	17.0	25.0	19.0	18.0	17.0
D_1	*ND	*ND	16.0	*ND	11.0	11.5	12.5	16.0	23.0	17.5	18.0	17.0
E_1	*ND	*ND	16.0	*ND	11.0	11.5	12.0	15.0	16.0	19.5	17.5	17.5
F_1	*ND	*ND	17.0	*ND	11.0	12.0	14.5	18.0	19.0	20.0	18.5	17.0
G_1	*ND	*ND	18.5	*ND	10.0	14.5	15.5	16.0	21.0	21.0	19.5	19.0
H_1	*ND	*ND	16.0	*ND	14.0	12.0	13.0	14.0	20.0	19.5	18.0	17.0
I_1	*ND	*ND	16.0	*ND	12.0	13.0	14.0	14.5	19.0	17.0	16.5	17.0
J_1	*ND	*ND	16.5	*ND	12.0	12.0	14.0	14.0	20.0	17.5	19.5	17.0
A_2	*ND	*ND	*ND	*ND	*ND	11.5	13.0	15.0	18.0	17.0	18.0	16.0
B_2	*ND	*ND	16.0	*ND	10.0	9.0	12.5	17.0	19.5	16.5	17.5	17.0
C_2	*ND	*ND	16.0	*ND	15.0	13.5	14.0	17.0	15.0	18.0	16.0	18.0
D_2	*ND	*ND	15.5	*ND	13.0	13.0	13.0	16.0	18.5	18.0	17.0	17.0
E_2	*ND	*ND	17.0	*ND	12.0	11.5	12.5	17.0	21.0	19.0	17.5	17.0
F_2	*ND	*ND	17.0	*ND	9.0	14.0	14.0	17.0	17.0	19.0	18.0	18.0
G_2	*ND	*ND	17.0	*ND	14.0	14.5	16.0	16.0	23.5	21.0	18.0	18.5
H_2	*ND	*ND	15.0	*ND	12.0	14.0	13.0	13.0	18.5	16.5	15.0	16.0
I_2	*ND	*ND	16.5	*ND	11.5	12.5	13.0	13.0	*ND	17.5	16.0	16.0
J_2	*ND	*ND	16.0	*ND	13.5	12.0	14.0	14.5	19.0	17.0	17.0	17.0
Ch	*ND	*ND	13.0	*ND	7.0	10.0	14.0	22.0	29.5	31.0	25.0	12.0
R	*ND	*ND	*ND	*ND	6.0	11.5	13.5	25.5	26.5	31.0	28.0	16.0

*ND = No Data

CONDUCTIVITY (mohs)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	1390	1400	950	*ND	2900	2700	3700	2950	2500	2300	2400	1800
B_1	6000	1620	1050	*ND	1700	1750	1600	5000	10000	8500	9000	1500
C_1	12400	9000	6800	*ND	8000	9000	8000	4600	7000	8000	8000	5050
D_1	*ND	340	460	*ND	2500	2250	3350	2100	2400	1750	1900	1600
E_1	*ND	1390	720	*ND	1500	1500	1500	1200	2600	1850	1800	1850
F_1	*ND	1810	2120	*ND	2200	1650	1850	1150	2100	1850	1800	1500
G_1	*ND	3660	3500	*ND	6500	3100	3300	3700	3700	7500	3400	3350
H_1	*ND	260	230	*ND	450	130	120	165	185	230	250	255
I_1	*ND	132	178	*ND	105	290	105	110	110	100	110	115
J_1	*ND	230	250	*ND	260	335	280	950	235	185	190	210
A_2	3550	2600	*ND	*ND	*ND	2800	1850	7050	1700	1700	2050	3050
B_2	*ND	2210	2100	*ND	2500	2300	2400	2600	2700	2500	2550	2300
C_2	7400	7200	3650	*ND	2000	1200	800	700	7500	900	950	950
D_2	*ND	1680	1500	*ND	1950	1900	2000	2000	2600	1250	1850	1800
E_2	*ND	1600	2790	*ND	2900	2700	2500	2600	2100	2500	2700	2950
F_2	*ND	1200	1730	*ND	1200	1000	800	700	900	1100	1100	850
G_2	*ND	3900	7500	*ND	10500	7000	7000	7000	7000	10000	6800	5000
H_2	*ND	405	410	*ND	130	450	430	430	440	400	420	445
I_2	*ND	109	130	*ND	110	265	100	105	135	120	175	160
J_2	*ND	300	330	*ND	330	300	320	1010	320	300	335	320
Ch	*ND	14800	8500	*ND	15000	4700	4100	10000	13500	18500	20000	14000
R	*ND	*ND	*ND	*ND	14000	8000	6500	11000	15000	20000	22000	13000

*ND = No Data

SALINITY ($^{o}/oo$)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	1.0	2.0	0.5	*ND	2.5	2.0	2.5	2.0	1.5	1.5	1.5	1.0
B_1	4.0	2.0	0.5	*ND	1.5	1.5	1.0	6.5	6.0	5.5	6.0	1.0
C_1	9.0	7.0	0.5	*ND	6.5	7.0	6.0	5.0	5.0	5.5	5.5	3.5
D_1	*ND	1.0	<0.5	*ND	2.0	3.0	2.5	1.5	1.5	1.0	1.0	1.0
E_1	*ND	2.0	<0.5	*ND	1.0	1.0	1.0	0.5	1.5	1.0	1.0	1.0
F_1	*ND	2.0	<0.5	*ND	2.0	1.0	1.5	0.5	1.5	1.0	1.0	1.0
G_1	*ND	4.0	2.5	*ND	5.0	2.0	2.5	2.5	2.0	5.0	2.0	2.0
H_1	*ND	0.5	<0.5	*ND	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
I_1	*ND	<0.5	<0.5	*ND	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
J_1	*ND	<0.5	<0.5	*ND	<0.5	<0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5
A_2	2.5	2.5	*ND	*ND	*ND	2.5	1.5	0.5	1.0	1.0	1.0	2.0
B_2	*ND	2.5	1.5	*ND	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5
C_2	5.0	5.0	0.5	*ND	1.5	1.0	0.5	0.5	0.5	0.5	0.5	0.5
D_2	*ND	2.0	1.0	*ND	1.5	1.0	1.5	1.0	1.5	0.5	1.0	1.0
E_2	*ND	2.0	<0.5	*ND	2.0	2.0	2.0	2.0	1.0	1.5	1.5	1.5
F_2	1.5	1.5	<0.5	*ND	1.0	0.5	0.5	<0.5	0.5	0.5	0.5	<0.5
G_2	*ND	5.0	5.0	*ND	8.0	5.0	5.0	5.0	4.0	6.5	4.5	4.5
H_2	*ND	0.5	<0.5	*ND	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
I_2	*ND	<0.5	<0.5	*ND	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
J_2	*ND	0.5	<0.5	*ND	<0.5	<0.5	<0.5	1.0	0.5	<0.5	<0.5	<0.5
Ch	*ND	9.5	6.5	*ND	14.0	4.0	3.0	6.0	7.0	9.5	12.0	10.5
R	*ND	*ND	*ND	*ND	13.0	6.0	5.0	6.5	8.5	10.0	12.5	11.0

*ND = No Data

NO_3 (mg/l)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	0.3	0.1	0.1	<0.1	<0.1	0.2	0.1	0.1	*ND	<0.1	0.1	0.1
B_1	0.2	0.1	0.2	0.1	0.2	0.1	0.1	<0.1	*ND	*ND	<0.1	0.1
C_1	0.6	0.3	<0.1	0.2	<0.1	0.8	<0.1	<0.1	*ND	*ND	<0.1	<0.1
D_1	0.1	<0.1	0.1	0.1	<0.1	0.1	<0.1	0.1	*ND	<0.1	0.2	0.2
E_1	0.1	0.1	0.1	0.1	<0.1	<0.1	0.1	0.2	*ND	0.1	<0.1	<0.1
F_1	0.1	0.1	0.1	<0.1	<0.1	0.1	0.1	0.1	*ND	<0.1	<0.1	0.1
G_1	0.2	0.1	0.1	0.1	<0.1	<0.1	0.1	0.1	*ND	0.1	0.1	<0.1
H_1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	*ND	<0.1	0.1	<0.1
I_1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	0.1	*ND	<0.1	<0.1	<0.1
J_1	<0.1	<0.1	0.1	<0.1	<0.1	0.1	0.1	0.1	*ND	0.1	0.5	1.0
A_2	0.1	<0.1	<0.1	0.1	*ND	0.4	0.1	0.1	*ND	<0.1	<0.1	0.1
B_2	0.3	<0.1	0.1	0.1	<0.1	0.3	0.1	0.1	*ND	<0.1	<0.1	<0.1
C_2	0.2	0.7	0.1	<0.1	<0.1	<0.1	<0.1	0.1	*ND	0.7	0.9	<0.1
D_2	<0.1	<0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	*ND	<0.1	<0.1	0.1
E_2	0.1	*ND	0.1	0.1	0.1	<0.1	<0.1	<0.1	*ND	0.1	0.2	0.1
F_2	0.1	<0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	*ND	<0.1	0.1	<0.1
G_2	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*ND	<0.1	<0.1	<0.1
H_2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	*ND	0.1	<0.1	<0.1
I_2	0.2	*ND	0.1	0.1	0.1	<0.1	0.1	0.1	*ND	0.1	0.2	0.3
J_2	0.9	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	*ND	<0.1	<0.1	0.1
Ch	*ND	0.1	0.3	0.2	0.3	0.4	0.2	0.1	*ND	<0.1	0.1	0.4
R	*ND	*ND	*ND	0.3	0.3	0.4	0.2	0.2	*ND	<0.1	0.1	0.3

*ND = No Data

NO_2 (ug/1)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	5	6	5	11	8	5	6	4	6	3	2	3
B_1	<1	9	9	12	10	15	9	<1	<1	<1	<1	14
C_1	<1	1	<1	*ND	4	1	*ND	35	<1	*ND	<1	*ND
D_1	*ND	8	7	4	1	6	7	10	7	4	2	4
E_1	*ND	7	4	3	15	13	11	*ND	5	5	4	10
F_1	1	3	2	6	6	6	4	10	2	*ND	3	15
G_1	1	4	1	*ND	5	1	3	2	1	<1	1	3
H_1	4	5	4	2	7	2	2	2	1	<1	<1	1
I_1	1	<1	<1	<1	<1	1	<1	<1	<1	<1	1	<
J_1	*ND	2	1	2	4	2	2	4	4	6	1	49
A_2	2	3	3	4	*ND	7	3	3	2	<1	<1	3
B_2	3	9	2	3	2	2	2	<1	<1	1	1	2
C_2	<1	6	1	3	2	3	4	10	17	16	1	14
D_2	*ND	1	1	3	2	14	1	9	<1	*ND	1	1
E_2	4	*ND	<1	*ND	*ND	<1	<1	9	*ND	*ND	7	9
F_2	2	2	1	*ND	*ND	1	1	1	1	*ND	5	1
G_2	2	10	<1	<1	10	1	1	9	<1	*ND	<1	*ND
H_2	*ND	2	3	1	*ND	3	2	5	3	1	1	3
I_2	*ND	*ND	*ND	<1	<1	2	2	2	1	*ND	1	22
J_2	*ND	4	9	<1	2	1	<1	12	1	1	<1	1
Ch	*ND	38	34	10	9	27	18	70	60	2	1	85
R	*ND	*ND	*ND	10	10	5	9	21	16	2	<1	13

*ND = No Data

TKN (mg/1)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	1.8	1.5	*ND	1.4	1.5	*ND	1.6	*ND	3.2	<0.1	*ND	<0.1
B_1	2.9	14.0	*ND	7.9	6.3	*ND	5.2	*ND	*ND	160	*ND	6.1
C_1	790	*ND	*ND	380	254	*ND	*ND	*ND	680	260	*ND	190
D_1	*ND	1.5	*ND	9.5	3.4	*ND	0.1	*ND	3.2	7	*ND	1.7
E_1	*ND	2.5	*ND	2.5	4.6	*ND	6.6	*ND	22	34	*ND	1.7
F_1	12.0	9.6	*ND	24	22	*ND	25	*ND	48	47	*ND	5.0
G_1	*ND	160.0	*ND	190	*ND	*ND	*ND	*ND	190	49	*ND	73
H_1	*ND	<0.1	*ND	0.4	0.3	*ND	0.5	*ND	0.4	1.9	*ND	0.9
I_1	*ND	<0.1	*ND	<0.1	0.3	*ND	0.3	*ND	0.1	1.9	*ND	0.9
J_1	*ND	<0.1	*ND	0.1	<0.1	*ND	<0.1	*ND	0.1	0.8	*ND	0.9
A_2	0.6	<0.1	*ND	0.3	0.4	*ND	0.2	*ND	0.7	0.6	*ND	0.3
B_2	1.4	<0.1	*ND	0.4	0.1	*ND	0.3	*ND	1.3	2.8	*ND	0.6
C_2	320.0	*ND	*ND	32	0.9	*ND	0.7	*ND	16	25	*ND	8.2
D_2	*ND	<0.1	*ND	0.8	0.7	*ND	0.6	*ND	5.1	1.6	*ND	1.2
E_2	*ND	*ND	*ND	3.2	1.8	*ND	1.4	*ND	2.9	8.8	*ND	3.4
F_2	8.8	9.2	*ND	9.6	6.4	*ND	3	*ND	*ND	6.6	*ND	1.7
G_2	*ND	*ND	*ND	210	156	*ND	*ND	*ND	410	84	*ND	214
H_2	*ND	<0.1	*ND	0.1	0.4	*ND	0.5	*ND	0.9	2.9	*ND	0.8
I_2	*ND	<0.1	*ND	0.1	0.4	*ND	0.5	*ND	0.3	1.5	*ND	<0.1
J_2	*ND	<0.1	*ND	0.4	0.6	*ND	0.9	*ND	0.1	0.8	*ND	<0.1
Ch	*ND	<0.1	*ND	0.2	0.3	*ND	0.6	*ND	5.6	1.6	*ND	1.5
R	*ND	*ND	*ND	0.2	0.3	*ND	0.8	*ND	0.6	0.8	*ND	0.9

*ND = No Data

TPO$_4$

SITE	9/2/82	9/3/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	0.01	0.13	0.12	0.05	0.06	0.07	0.06	*ND	*ND	0.05	0.06	0.04
B_1	0.80	0.33	0.27	0.18	0.17	0.24	0.21	*ND	*ND	1.30	0.93	0.24
C_1	1.70	1.66	1.50	1.07	1.97	1.71	1.82	*ND	*ND	2.40	1.40	1.60
D_1	0.22	0.07	0.10	0.01	0.02	0.05	0.03	*ND	*ND	0.03	0.03	<0.01
E_1	1.25	0.07	0.11	0.06	0.03	0.07	0.04	*ND	*ND	0.02	0.04	0.02
F_1	0.15	0.09	0.11	0.07	0.07	0.10	0.06	*ND	*ND	<0.01	0.09	0.04
G_1	0.09	0.06	0.15	0.18	0.16	0.13	0.14	*ND	*ND	0.67	0.36	0.07
H_1	0.07	0.02	0.03	<0.01	0.04	0.02	0.03	*ND	*ND	<0.01	0.02	<0.01
I_1	0.06	0.10	0.03	<0.01	<0.01	0.01	0.01	*ND	*ND	<0.01	<0.01	<0.01
J_1	0.15	*ND	0.05	<0.01	0.03	0.02	0.02	*ND	*ND	0.01	0.01	<0.01
A_2	0.44	0.02	0.04	<0.01	*ND	0.02	0.02	*ND	*ND	<0.01	<0.01	<0.01
B_2	1.20	0.04	0.04	<0.01	0.01	0.02	0.02	*ND	*ND	0.01	0.02	<0.01
C_2	0.61	0.32	0.41	0.03	0.07	0.05	0.03	*ND	*ND	0.08	0.12	0.05
D_2	1.18	0.10	0.03	<0.01	0.02	0.02	0.02	*ND	*ND	0.08	0.01	<0.01
E_2	2.20	*ND	0.05	0.02	0.04	0.04	0.04	*ND	*ND	0.03	0.03	<0.01
F_2	0.22	0.02	0.04	0.02	0.02	0.03	0.03	*ND	*ND	<0.01	0.02	<0.01
G_2	1.16	1.14	1.59	1.46	1.41	1.25	1.38	*ND	*ND	1.60	1.10	1.50
H_2	0.15	0.01	0.01	<0.01	0.01	0.01	0.01	*ND	*ND	0.02	0.03	<0.01
I_2	1.40	*ND	0.07	<0.01	0.01	0.01	0.01	*ND	*ND	<0.01	<0.01	<0.01
J_2	1.10	0.04	0.06	0.03	0.08	0.05	0.07	*ND	*ND	0.04	0.08	0.07
Ch	*ND	0.06	0.07	0.03	0.03	0.03	0.03	*ND	*ND	0.06	0.09	0.03
R	*ND	*ND	*ND	0.03	0.03	0.03	0.03	*ND	*ND	0.05	0.05	0.06

*ND = No Data

OPO_4

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	*ND	*ND	0.07	0.03	0.04	<0.01	0.02	0.04	0.05	*ND	0.04	0.04
B_1	*ND	*ND	0.24	0.18	0.12	0.20	0.34	0.58	0.96	*ND	0.95	0.21
C_1	*ND	*ND	*ND	1.27	1.29	1.30	1.40	1.80	2.67	*ND	2.50	1.50
D_1	*ND	*ND	0.05	<0.01	0.01	<0.01	0.01	<0.01	0.01	*ND	0.01	0.02
E_1	*ND	*ND	0.06	0.07	0.02	0.01	0.04	0.02	<0.01	*ND	0.01	0.02
F_1	*ND	*ND	0.06	0.03	0.05	<0.01	0.06	0.04	0.05	*ND	0.05	0.04
G_1	*ND	*ND	0.05	0.11	0.10	0.30	0.43	0.56	0.73	*ND	0.28	0.06
H_1	*ND	*ND	<0.01	<0.01	0.02	<0.01	<0.01	0.03	0.01	*ND	<0.01	0.01
I_1	*ND	*ND	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*ND	<0.01	<0.01
J_1	*ND	*ND	0.01	0.01	0.02	<0.01	0.01	<0.01	<0.01	*ND	<0.01	0.01
A_2	*ND	*ND	<0.01	<0.01	*ND	<0.01	<0.01	<0.01	0.01	*ND	<0.01	<0.01
B_2	*ND	*ND	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*ND	<0.01	<0.01
C_2	*ND	*ND	0.03	0.05	0.03	0.01	0.02	0.01	0.09	*ND	0.07	0.06
D_2	*ND	*ND	<0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	*ND	<0.01	<0.01
E_2	*ND	*ND	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*ND	<0.01	<0.01
F_2	*ND	*ND	<0.01	0.02	0.01	<0.01	<0.01	0.01	<0.01	*ND	<0.01	<0.01
G_2	*ND	*ND	*ND	1.14	1.11	1.10	1.20	1.30	1.30	*ND	1.30	1.40
H_2	*ND	*ND	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*ND	<0.01	0.01
I_2	*ND	*ND	0.02	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*ND	<0.01	0.01
J_2	*ND	*ND	0.03	0.08	0.60	0.10	0.05	0.02	0.02	*ND	0.04	0.08
Ch	*ND	*ND	0.03	<0.01	0.01	<0.01	0.02	0.03	0.05	*ND	0.04	0.04
R	*ND	*ND	*ND	<0.01	0.01	<0.01	<0.01	0.02	0.02	*ND	0.01	0.03

*ND = No Data

SO_4 (mg/l)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	17	<1	<1	35	43	*ND	53	89	*ND	3	18	5
B_1	10	<1	<1	45	10	9	10	11	*ND	16	20	<1
C_1	10	15	15	15	11	12	15	10	*ND	6	13	11
D_1	*ND	19	13	75	53	62	39	110	*ND	48	120	91
E_1	*ND	<1	<1	7	5	6	5	7	*ND	27	4	<1
F_1	<1	<1	8	10	9	8	8	5	*ND	2	4	<1
G_1	*ND	6	4	4	7	5	9	13	*ND	<1	3	<1
H_1	*ND	7	5	6	9	10	7	10	*ND	2	7	3
I_1	*ND	26	28	23	25	27	26	21	*ND	6	7	25
J_1	*ND	20	17	12	15	18	11	13	*ND	17	<1	21
A_2	<1	<1	*ND	190	<1	75	43	31	*ND	17	30	80
B_2	8	<1	<1	6	6	4	8	21	*ND	17	22	16
C_2	11	10	<1	6	5	5	4	5	*ND	<1	4	4
D_2	*ND	5	3	<1	<1	<1	<1	4	*ND	<1	4	4
E_2	*ND	*ND	<1	<1	<1	<1	<1	4	*ND	<1	6	3
F_2	<1	<1	<1	<1	<1	<1	<1	5	*ND	<1	3	3
G_2	*ND	7	10	10	9	9	10	9	*ND	8	10	11
H_2	*ND	8	4	4	5	5	5	5	*ND	1	7	4
I_2	*ND	*ND	31	4	5	4	4	4	*ND	*ND	25	4
J_2	*ND	10	8	8	9	8	8	9	*ND	6	20	360
Ch	*ND	950	*ND	540	160	340	94	210	*ND	800	510	1540
R	*ND	*ND	*ND	560	180	320	110	180	*ND	700	490	37

*ND = No Data

Cl (mg/l)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	*ND	293	226	442	714	*ND	878	1330	*ND	1140	*ND	780
B_1	*ND	191	258	636	485	*ND	533	1030	*ND	2740	*ND	525
C_1	*ND	1270	1340	1330	1180	*ND	1290	1090	*ND	2270	*ND	1380
D_1	*ND	200	162	994	1030	*ND	863	729	*ND	1000	*ND	750
E_1	*ND	384	345	333	569	*ND	374	457	*ND	1150	*ND	660
F_1	*ND	365	408	571	580	*ND	480	411	*ND	800	*ND	570
G_1	*ND	881	447	411	335	*ND	533	657	*ND	1040	*ND	680
H_1	*ND	49	42	36	34	*ND	36	34	*ND	110	*ND	90
I_1	*ND	22	20	18	82	*ND	20	7	*ND	30	*ND	20
J_1	*ND	26	29	27	33	*ND	29	25	*ND	36	*ND	40
A_2	*ND	771	1370	2223	*ND	*ND	563	385	*ND	1090	*ND	1490
B_2	*ND	647	548	1128	757	*ND	870	848	*ND	1500	*ND	1070
C_2	*ND	1140	705	303	207	*ND	154	70	*ND	270	*ND	230
D_2	*ND	483	429	460	537	*ND	512	524	*ND	880	*ND	620
E_2	*ND	*ND	835	762	726	*ND	969	666	*ND	1230	*ND	1010
F_2	*ND	314	415	460	206	*ND	187	71	*ND	370	*ND	220
G_2	*ND	1190	1120	1073	1060	*ND	1020	1110	*ND	1950	*ND	1390
H_2	*ND	44	53	51	63	*ND	56	48	*ND	100	*ND	90
I_2	*ND	*ND	8	11	12	*ND	10	7	*ND	25	*ND	30
J_2	*ND	15	14	14	3	*ND	12	9	*ND	30	*ND	30
Ch	*ND	5710	4170	3296	6060	*ND	4380	3564	*ND	8030	*ND	8850
R	*ND	*ND	*ND	3598	6310	*ND	4630	3050	*ND	8530	*ND	8650

*ND = No Data

Na (mg/1)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	940	710	370	390	710	840	870	1020	580	540	570	480
B_1	310	220	180	310	590	680	590	870	2130	2180	2090	390
C_1	940	790	790	840	970	1010	970	790	810	840	860	690
D_1	240	210	170	620	860	730	1030	700	480	440	500	490
E_1	410	330	280	320	610	560	540	510	410	430	470	430
F_1	310	360	370	490	650	580	570	550	450	470	430	390
G_1	460	350	350	380	530	510	560	680	550	490	460	460
H_1	35	38	35	31	53	*ND	49	53	43	47	52	52
I_1	19	19	19	18	39	38	38	37	23	23	51	24
J_1	25	25	27	27	53	58	58	51	34	29	29	31
A_2	590	640	940	1240	*ND	890	790	570	500	620	620	810
B_2	620	590	610	640	830	830	780	850	660	770	670	64
C_2	850	860	600	320	450	410	360	440	180	220	250	220
D_2	360	360	360	400	640	620	630	650	630	490	500	510
E_2	380	*ND	620	600	790	760	770	750	600	650	670	670
F_2	430	270	330	420	460	449	370	400	260	260	260	230
G_2	890	900	870	880	1060	990	1030	980	890	1900	800	770
H_2	28	41	47	49	76	71	71	70	55	57	60	63
I_2	19	*ND	16	14	35	35	35	36	29	20	21	22
J_2	21	17	17	17	39	39	39	39	24	25	24	25
Ch	*ND	*ND	*ND	*ND	6500	3900	3500	4900	3900	5180	6090	5180
R	*ND	*ND	*ND	*ND	6800	4400	3800	4600	3990	5420	4940	4750

*ND = No Data

K (mg/l)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	660	42	38	42	63	61	64	70	61	63	62	53
B_1	38	130	110	66	41	33	33	120	1500	1520	1500	110
C_1	1470	1210	1260	1330	1250	1470	1390	1030	1480	1510	1530	1090
D_1	16	8	7	35	28	42	45	33	33	42	39	37
E_1	72	35	29	35	57	89	94	140	200	160	140	130
F_1	74	54	48	48	60	44	54	69	81	92	87	87
G_1	540	420	420	420	460	43	450	430	520	500	4440	420
H_1	2	2	2	1	2	*ND	1	1	2	2	2	2
I_1	2	2	2	2	2	2	2	2	2	2	2	2
J_1	3	2	2	2	2	2	2	2	2	2	2	3
A_2	27	15	29	44	*ND	80	80	50	27	19	18	37
B_2	16	15	14	14	130	140	140	150	18	19	18	16
C_2	640	730	300	120	93	75	53	43	45	53	62	57
D_2	17	11	11	13	18	18	18	18	15	15	15	15
E_2	40	*ND	29	29	32	30	28	26	28	29	29	31
F_2	76	18	3	3	18	26	13	10	13	11	13	9
G_2	540	970	920	780	960	840	940	920	1040	1020	1090	1120
H_2	3	3	3	3	6	5	5	5	5	5	5	6
I_2	27	*ND	3	2	2	2	2	2	3	2	2	3
J_2	5	2	2	2	2	2	2	2	2	2	2	3
Ch	*ND	120	91	74	158	65	45	106	130	180	260	170
R	*ND	*ND	*ND	81	160	75	55	82	120	190	170	170

*ND = No Data

Ca (mg/l)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	120	47	42	77	110	110	110	100	92	96	96	71
B_1	43	85	74	74	130	80	70	150	150	150	140	92
C_1	74	74	88	81	100	90	90	90	85	78	71	99
D_1	18	15	12	51	50	60	60	60	31	28	29	27
E_1	70	41	31	38	43	43	34	23	78	64	46	23
F_1	43	59	51	77	70	60	70	60	64	53	56	34
G_1	62	55	51	66	80	80	80	70	75	75	78	75
H_1	10	13	12	7	8	*ND	6	9	12	15	16	17
I_1	3	3	3	3	4	4	4	4	4	4	4	4
J_1	29	28	30	31	34	38	36	32	30	27	27	31
A_2	126	120	126	107	*ND	80	80	50	78	110	110	120
B_2	110	100	110	122	130	140	140	150	150	150	140	140
C_2	85	100	144	92	80	80	70	60	68	82	89	82
D_2	110	96	100	118	140	140	150	110	120	110	120	110
E_2	160	*ND	210	210	220	200	200	190	190	200	250	260
F_2	331	141	167	197	130	120	100	90	130	140	140	110
G_2	210	120	110	110	120	110	120	110	110	110	110	95
H_2	23	51	66	66	80	80	80	80	81	85	85	89
I_2	100	*ND	15	9	12	12	12	12	10	10	11	11
J_2	62	66	66	66	80	100	80	80	85	85	85	82
Ch	*ND	126	100	77	160	60	50	100	120	170	210	170
R	*ND	*ND	*ND	96	160	80	60	90	110	170	150	160

*ND = No Data

Mg (mg/1)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	88	19	17	36	42	70	70	90	42	45	41	33
B_1	17	27	21	25	33	27	28	100	130	140	130	28
C_1	120	110	120	120	110	120	120	90	100	100	100	90
D_1	25	17	15	86	90	80	100	70	42	37	44	40
E_1	88	22	16	23	37	32	32	29	46	42	39	25
F_1	34	63	57	91	80	70	70	60	60	60	70	50
G_1	81	67	62	79	70	70	80	70	70	70	60	60
H_1	4	4	4	3	3	*ND	3	3	4	4	5	4
I_1	8	7	7	6	5	5	5	5	6	6	6	6
J_1	5	2	3	3	4	4	4	4	3	2	2	2
A_2	62	48	91	140	70	*ND	60	24	33	43	43	80
B_2	49	36	39	39	38	37	38	44	42	42	41	37
C_2	100	110	34	26	17	14	10	9	9	11	13	11
D_2	64	39	41	46	27	41	42	43	40	37	39	39
E_2	64	*ND	86	86	90	90	80	80	70	70	80	90
F_2	240	35	46	64	24	21	16	13	23	22	13	15
G_2	260	160	150	150	150	140	150	130	150	139	130	110
H_2	4	4	5	5	5	5	5	5	5	5	5	5
I_2	79	*ND	6	5	4	4	4	4	3	3	4	4
J_2	10	4	4	4	3	3	3	3	4	4	4	4
Ch	*ND	410	290	250	430	140	120	260	320	460	600	440
R	*ND	*ND	*ND	*ND	450	190	140	220	310	480	430	430

*ND = No Data

Fe (mg/l)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	3.9	3.9	3.9	7.0	9.1	7.9	11.0	3.3	6.7	7.0	5.8	5.5
B_1	4.0	5.2	7.8	12.0	19.0	11.0	9.8	7.9	2.3	1.4	1.1	9.9
C_1	1.8	2.6	3.7	3.0	4.5	1.5	2.6	4.1	2.3	0.3	0.3	6.5
D_1	18.0	2.6	2.4	31.0	12.0	17.0	26.0	17.0	17.0	14.0	20.0	17.0
E_1	3.3	1.7	1.3	4.4	15.0	11.0	3.3	19.0	22.0	8.1	2.3	3.6
F_1	86.0	1.6	3.0	4.0	3.6	2.7	3.4	5.4	3.6	3.6	5.3	9.6
G_1	17.0	3.0	3.1	1.2	7.6	2.6	10.0	12.0	13.0	12.0	11.0	2.5
H_1	9.0	3.1	1.8	3.5	2.4	*ND	2.1	2.0	2.6	2.6	2.5	2.3
I_1	11.0	0.9	0.8	0.2	0.3	0.4	0.4	0.3	0.9	1.5	1.6	1.0
J_1	15.0	1.3	1.6	1.6	2.7	2.7	2.9	1.8	1.2	0.4	0.2	0.1
A_2	140.0	1.4	3.4	1.3	*ND	1.3	1.8	1.7	1.9	1.7	0.4	0.4
B_2	30.0	1.2	0.8	0.6	0.4	0.3	0.3	0.7	0.4	1.7	0.2	0.2
C_2	7.4	6.2	2.5	0.5	0.6	0.4	0.5	0.6	0.5	0.6	0.8	0.3
D_2	120.0	0.3	0.1	0.7	0.7	0.6	0.2	0.1	<0.1	1.9	0.2	0.7
E_2	9.0	*ND	16.0	16.0	20.0	17.0	9.0	0.2	9.0	7.3	15.0	9.6
F_2	630.0	0.6	1.7	2.0	0.2	0.4	0.6	0.3	0.1	1.2	0.4	0.2
G_2	260.0	4.7	0.9	0.9	2.1	1.7	1.5	1.7	1.0	2.4	0.8	1.4
H_2	13.0	0.4	0.2	0.3	0.1	0.1	0.1	0.3	0.2	0.2	0.2	0.2
I_2	460.0	*ND	8.2	1.2	0.3	1.0	0.1	0.1	4.3	14.0	12.0	15.0
J_2	8.2	0.1	<0.1	<0.1	0.4	0.1	0.1	0.1	0.2	0.1	0.6	0.2
Ch	*ND	0.3	0.4	0.4	0.3	0.8	0.7	1.0	0.7	0.2	0.2	0.3
R	*ND	*ND	*ND	0.4	0.4	0.6	0.7	0.9	0.5	0.2	0.2	0.2

*ND = No Data

Mn (mg/l)

SITE	9/2/82	9/30/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	1.1	0.2	0.3	0.2	0.7	0.8	0.7	0.5	0.5	0.5	0.5	0.4
B_1	0.3	0.2	0.2	2.1	0.5	0.3	0.2	0.4	0.3	0.3	0.3	0.4
C_1	0.3	0.4	0.5	0.4	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.4
D_1	0.1	0.1	0.1	0.3	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
E_1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.3	0.2	0.2	0.1
F_1	0.5	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
G_1	0.4	0.4	0.3	0.3	0.6	0.4	0.5	0.7	0.4	0.4	0.5	0.4
H_1	<0.1	<0.1	<0.1	<0.1	<0.1	*ND	<0.1	<0.1	0.1	0.1	0.1	0.1
I_1	0.1	0.1	0.1	0.1	0.1	0.1	<0.1	<0.1	0.1	0.1	0.1	0.1
J_1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2
A_2	0.4	0.3	0.3	0.5	*ND	0.2	0.2	0.1	0.2	0.2	<0.1	0.2
B_2	0.3	0.4	0.3	0.4	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2
C_2	0.2	0.3	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1
D_2	1.1	0.2	0.2	0.3	0.3	0.2	0.2	0.3	0.1	0.3	0.3	0.3
E_2	0.3	*ND	0.6	0.6	0.7	0.6	0.6	0.5	0.5	0.5	0.6	0.5
F_2	11.0	0.2	0.2	0.3	0.1	0.1	<0.1	<0.1	0.1	0.1	0.1	0.1
G_2	2.7	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3
H_2	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
I_2	4.5	*ND	0.2	0.2	0.2	<0.1	<0.1	0.1	0.4	0.4	0.5	0.4
J_2	0.4	0.2	0.2	0.2	0.1	<0.1	0.1	0.1	0.2	0.2	0.2	0.2
Ch	*ND	0.1	0.1	<0.1	<0.1	<0.1	<0.1	0.2	0.2	0.1	0.2	0.1
R	*ND	*ND	*ND	<0.1	<0.1	<0.1	0.1	0.1	0.1	0.1	0.1	0.1

*ND = No Data

Zn (mg/l)

SITE	9/2/82	9/3/82	10/28/82	12/20/82	1/29/83	3/6/83	4/17/83	6/3/83	7/1/83	7/29/83	8/28/83	10/30/83
A_1	<0.01	<0.01	<0.11	0.08	0.07	0.39	0.07	0.05	0.03	0.01	0.01	0.03
B_1	0.02	0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
C_1	0.01	0.01	0.01	<0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
D_1	0.04	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01
E_1	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
F_1	0.21	0.01	0.01	0.01	0.01	<0.01	0.01	0.01	<0.01	<0.01	0.01	<0.01
G_1	<0.01	<0.01	<0.01	0.01	0.02	0.05	0.05	0.01	0.01	<0.01	0.01	0.01
H_1	0.01	<0.01	<0.01	<0.01	0.03	*ND	0.01	0.01	0.02	0.10	0.01	0.01
I_1	0.03	0.01	<0.01	<0.01	0.01	0.01	0.01	0.02	0.01	<0.01	0.01	0.01
J_1	0.03	<0.01	<0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	<0.01
A_2	0.44	<0.01	0.30	0.35	*ND	*ND	0.38	0.23	0.10	0.02	0.01	0.13
B_2	0.08	0.01	<0.01	<0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
C_2	0.01	0.06	0.01	0.01	0.03	0.05	0.01	0.03	0.01	0.01	0.04	0.02
D_2	0.18	0.01	<0.01	0.01	<0.01	0.01	0.02	<0.01	0.01	0.01	0.06	0.06
E_2	<0.01	*ND	0.01	0.01	0.01	<0.01	<0.01	0.01	0.01	0.01	<0.01	0.01
F_2	2.90	<0.01	<0.01	<0.01	0.03	0.06	0.05	<0.01	0.01	<0.01	0.02	0.03
G_2	1.30	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.02
H_2	0.05	<0.01	<0.01	0.01	0.05	0.04	0.02	0.04	0.02	0.02	0.01	0.01
I_2	1.90	*ND	0.03	<0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.03	0.02
J_2	0.14	<0.01	<0.01	<0.01	0.01	0.05	<0.01	0.05	<0.01	<0.01	0.01	0.01
Ch	*ND	0.02	0.03	0.02	0.04	0.02	0.01	<0.01	0.01	0.01	0.01	0.01
R	*ND	*ND	*ND	0.02	0.06	0.03	0.02	0.02	0.02	0.02	0.01	0.02

*ND = No Data

Appendix D. General descriptive statistics for all parameters by sample site, Chesapeake Landfill.

pH

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	12	6.283	0.144	6.050	6.500	0.450
	B1	12	6.629	0.319	6.300	7.100	0.800
	C1	12	7.008	0.122	6.750	7.200	0.450
	D1	12	5.657	0.248	5.300	6.100	0.800
	E1	12	5.908	0.270	5.200	6.200	1.000
	F1	11	6.214	0.179	5.900	6.500	0.600
	G1	12	6.833	0.197	6.600	7.200	0.600
	H1	12	5.633	0.421	5.000	6.650	1.650
	I1	12	5.067	0.253	4.700	5.600	0.900
	J1	12	5.983	0.163	5.800	6.300	0.500
Lower Wells	A2	10	6.723	0.164	6.350	6.900	0.550
	B2	12	6.762	0.123	6.580	6.950	0.370
	C2	12	7.037	0.141	6.700	7.200	0.500
	D2	12	6.917	0.168	6.650	7.300	0.650
	E2	11	6.691	0.199	6.450	7.000	0.550
	F2	12	6.731	0.171	6.400	7.000	0.600
	G2	12	7.058	0.143	6.800	7.300	0.500
	H2	12	6.854	0.331	6.250	7.250	1.000
	I2	11	5.977	0.365	5.500	6.700	1.200
	J2	12	6.696	0.203	6.400	7.000	0.600
Surface Water	Channel	11	6.877	0.239	6.650	7.450	0.800
	River	9	6.811	0.233	6.400	7.150	0.750
Site Type							
Upper Wells		119	6.122	0.619	4.700	7.200	2.500
Lower Wells		116	6.752	0.350	5.500	7.300	1.800
Surface Water		20	6.847	0.233	6.400	7.450	1.050
Total		255	6.465	0.585	4.700	7.450	2.750

Eh

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	12	-75.833	69.865	-190.000	65.000	255.000
	B1	12	-93.333	75.749	-200.000	60.000	260.000
	C1	12	-54.500	74.616	-160.000	60.000	220.000
	D1	12	-43.333	61.583	-140.000	110.000	250.000
	E1	12	-103.333	70.657	-180.000	70.000	250.000
	F1	11	-117.727	67.504	-200.000	-10.000	190.000
	G1	12	-23.333	78.287	-110.000	150.000	260.000
	H1	12	-8.750	64.495	-70.000	130.000	200.000
	I1	12	90.833	70.737	10.000	255.000	245.000
	J1	12	0.833	78.475	-80.000	190.000	270.000
Lower Wells	A2	10	-44.400	57.574	-120.000	75.000	195.000
	B2	12	-57.500	63.264	-140.000	50.000	190.000
	C2	12	-66.667	67.767	-160.000	50.000	210.000
	D2	12	-66.667	49.604	-160.000	30.000	190.000
	E2	11	-86.818	50.412	-170.000	10.000	180.000
	F2	12	-62.417	67.629	-170.000	70.000	240.000
	G2	12	-46.250	87.311	-210.000	110.000	320.000
	H2	12	-20.833	76.569	-100.000	130.000	230.000
	I2	11	4.091	59.867	-90.000	120.000	210.000
	J2	12	-22.500	117.328	-120.000	220.000	340.000
Surface Water	Channel	11	7.273	84.064	-100.000	180.000	280.000
	River	9	28.333	102.652	-170.000	150.000	320.000
Site Type							
Upper Wells		119	-42.218	90.333	-200.000	255.000	455.000
Lower Wells		116	-47.138	74.477	-210.000	220.000	430.000
Surface Water		20	16.750	90.949	-170.000	180.000	350.000
Total		255	-39.831	84.853	-210.000	255.000	465.000

Temperature (C)

Site Type	Site	Num. Sapl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	9	16.000	3.783	10.000	20.000	10.000
	B1	9	15.667	4.670	9.000	23.000	14.000
	C1	9	16.556	4.011	12.000	25.000	13.000
	D1	9	15.833	3.767	11.000	23.000	12.000
	E1	9	15.111	2.998	11.000	19.500	8.500
	F1	9	16.333	3.152	11.000	20.000	9.000
	G1	9	17.222	3.580	10.000	21.000	11.000
	H1	9	15.944	2.877	12.000	20.000	8.000
	I1	9	15.444	2.228	12.000	19.000	7.000
	J1	9	15.833	2.990	12.000	20.000	8.000
Lower Wells	A2	7	15.500	2.500	11.500	18.000	6.500
	B2	9	15.000	3.623	9.000	19.500	10.500
	C2	9	15.833	1.620	13.500	18.000	4.500
	D2	9	15.667	2.194	13.000	18.500	5.500
	E2	9	16.056	3.311	11.500	21.000	9.500
	F2	9	15.889	3.100	9.000	19.000	10.000
	G2	9	17.611	3.070	14.000	23.500	9.500
	H2	9	14.778	2.033	12.000	18.500	6.500
	I2	8	14.500	2.236	11.500	17.500	6.000
	J2	9	15.556	2.200	12.000	19.000	7.000
Surface Water	Channel	9	18.167	8.860	7.000	31.000	24.000
	River	8	19.750	9.130	6.000	31.000	25.000
Site Type							
Upper Wells		90	15.994	3.337	9.000	25.000	16.000
Lower Wells		87	15.655	2.657	9.000	23.500	14.500
Surface Water		17	18.912	8.740	6.000	31.000	25.000
Total		194	16.098	3.925	6.000	31.000	25.000

Conductivity (umohs)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	11	2271.818	815.743	950.000	3700.000	2750.000
	B1	11	4338.182	3488.859	1050.000	10000	8950.000
	C1	11	7804.545	2089.073	4600.000	12400	7800.000
	D1	10	1870.000	915.800	340.000	3350.000	3010.000
	E1	10	1591.000	491.335	720.000	2600.000	1880.000
	F1	10	1803.000	314.892	1150.000	2200.000	1050.000
	G1	10	4171.000	1521.538	3100.000	7500.000	4400.000
	H1	10	227.500	93.460	120.000	450.000	330.000
	I1	10	135.500	58.860	100.000	290.000	190.000
	J1	10	312.500	228.330	185.000	950.000	765.000
Lower Wells	A2	9	2927.778	1675.767	1700.000	7050.000	5350.000
	B2	10	2416.000	187.391	2100.000	2700.000	600.000
	C2	11	3022.727	2912.934	700.000	7500.000	6800.000
	D2	10	1853.000	354.935	1250.000	2600.000	1350.000
	E2	10	2534.000	407.573	1600.000	2950.000	1350.000
	F2	10	1058.000	290.930	700.000	1730.000	1030.000
	G2	10	7170.000	1968.107	3900.000	10500	6600.000
	H2	10	396.000	94.980	130.000	450.000	320.000
	I2	10	140.900	49.948	100.000	265.000	165.000
	J2	10	386.500	219.470	300.000	1010.000	710.000
Surface Water	Channel	10	12310	5378.238	4100.000	20000	15900
	River	8	13687.5	5378.114	6500.000	22000	15500
Site Type							
Upper Wells		103	2521.019	2714.660	100.000	12400	12300
Lower Wells		100	2191.440	2312.232	100.000	10500	10400
Surface Water		18	12922.2	5264.929	4100.000	22000	17900
Total		221	3219.045	4046.725	100.000	22000	21900

Salinity (o/oo)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	11	1.636	0.636	0.500	2.500	2.000
	B1	11	2.955	2.127	0.500	6.000	5.500
	C1	11	5.318	2.305	0.500	9.000	8.500
	D1	10	1.450	0.864	0.000	3.000	3.000
	E1	10	1.000	0.527	0.000	2.000	2.000
	F1	10	1.150	0.626	0.000	2.000	2.000
	G1	10	2.950	1.235	2.000	5.000	3.000
	H1	10	0.100	0.211	0.000	0.500	0.500
	I1	10	0.000	0.000	0.000	0.000	0.000
	J1	10	0.050	0.158	0.000	0.500	0.500
Lower Wells	A2	9	1.611	0.782	0.500	2.500	2.000
	B2	10	1.750	0.354	1.500	2.500	1.000
	C2	11	1.455	1.781	0.500	5.000	4.500
	D2	10	1.200	0.422	0.500	2.000	1.500
	E2	10	1.550	0.643	0.000	2.000	2.000
	F2	11	0.591	0.539	0.000	1.500	1.500
	G2	10	5.250	1.161	4.000	8.000	4.000
	H2	10	0.050	0.158	0.000	0.500	0.500
	I2	10	0.000	0.000	0.000	0.000	0.000
	J2	10	0.200	0.350	0.000	1.000	1.000
Surface Water	Channel	10	8.150	3.473	3.000	14.000	11.000
	River	8	9.063	3.041	5.000	13.000	8.000
Site Type							
Upper Wells		103	1.709	1.972	0.000	9.000	9.000
Lower Wells		101	1.356	1.641	0.000	8.000	8.000
Surface Water		18	8.556	3.226	3.000	14.000	11.000
Total		222	2.104	2.744	0.000	14.000	14.000

Hardness (mg/l)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	12	438.500	157.746	182.000	671.000	489.000
	B1	12	514.167	287.239	185.000	954.000	769.000
	C1	12	663.667	51.748	590.000	724.000	134.000
	D1	12	342.500	177.125	96.000	608.000	512.000
	E1	12	273.500	115.612	146.000	543.000	397.000
	F1	12	427.667	68.658	308.000	575.000	267.000
	G1	12	479.667	44.730	389.000	548.000	159.000
	H1	11	49.273	11.917	31.000	65.000	34.000
	I1	12	36.833	7.941	31.000	60.000	29.000
	J1	12	95.750	15.304	76.000	120.000	44.000
Lower Wells	A2	10	541.500	202.942	227.000	847.000	620.000
	B2	12	500.583	47.500	401.000	557.000	156.000
	C2	12	342.833	176.285	188.000	714.000	526.000
	D2	12	486.417	94.047	401.000	755.000	354.000
	E2	11	873.364	102.804	680.000	1038.000	358.000
	F2	12	653.750	740.575	279.000	2968.000	2689.000
	G2	12	962.000	355.311	693.000	2067.000	1374.000
	H2	12	202.500	42.928	97.000	243.000	146.000
	I2	11	178.818	408.507	46.000	1410.000	1364.000
	J2	12	214.000	23.657	182.000	262.000	80.000
Surface Water	Channel	11	1697.818	722.060	620.000	2995.000	2375.000
	River	8	1670.500	656.024	728.000	2401.000	1673.000
Site Type							
Upper Wells		119	334.529	237.277	31.000	954.000	923.000
Lower Wells		116	494.259	394.814	46.000	2968.000	2922.000
Surface Water		19	1686.316	676.172	620.000	2995.000	2375.000
Total		254	508.594	498.147	31.000	2995.000	2964.000

Nitrate (mg/l)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	11	0.100	0.089	0.000	0.300	0.300
	B1	10	0.110	0.074	0.000	0.200	0.200
	C1	10	0.190	0.292	0.000	0.800	0.800
	D1	11	0.082	0.075	0.000	0.200	0.200
	E1	11	0.073	0.065	0.000	0.200	0.200
	F1	11	0.064	0.050	0.000	0.100	0.100
	G1	11	0.082	0.060	0.000	0.200	0.200
	H1	11	0.018	0.040	0.000	0.100	0.100
	I1	11	0.018	0.040	0.000	0.100	0.100
	J1	11	0.182	0.306	0.000	1.000	1.000
Lower Wells	A2	10	0.090	0.120	0.000	0.400	0.400
	B2	11	0.091	0.114	0.000	0.300	0.300
	C2	11	0.245	0.345	0.000	0.900	0.900
	D2	11	0.027	0.047	0.000	0.100	0.100
	E2	10	0.080	0.063	0.000	0.200	0.200
	F2	11	0.036	0.050	0.000	0.100	0.100
	G2	11	0.013	0.060	0.000	0.200	0.200
	H2	11	0.018	0.040	0.000	0.100	0.100
	I2	10	0.140	0.084	0.000	0.300	0.300
	J2	11	0.064	0.050	0.000	0.100	0.100
Surface Water	Channel	10	0.210	0.137	0.000	0.400	0.400
	River	8	0.225	0.128	0.000	0.400	0.400

Site Type	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	108	0.091	0.148	0.000	1.000	1.000
Lower Wells	107	0.080	0.142	0.000	0.900	0.900
Surface Water	18	0.217	0.129	0.000	0.400	0.400
Total	233	0.096	0.148	0.000	1.000	1.000

Nitrite (ug/1)

Site Type	Site	Num. Sapl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	12	5.333	2.425	2.000	11.000	9.000
	B1	12	6.500	6.038	0.000	15.000	15.000
	C1	8	5.125	12.147	0.000	35.000	35.000
	D1	11	5.455	2.697	1.000	10.000	9.000
	E1	10	7.700	4.244	3.000	15.000	12.000
	F1	11	5.273	4.125	1.000	15.000	14.000
	G1	11	2.000	1.549	0.000	5.000	5.000
	H1	12	2.500	2.111	0.000	7.000	7.000
	I1	12	0.250	0.452	0.000	1.000	1.000
	J1	11	7.000	14.014	1.000	49.000	48.000
Lower Wells	A2	11	2.727	1.902	0.000	7.000	7.000
	B2	12	2.208	2.350	0.000	9.000	9.000
	C2	12	6.417	6.201	0.000	17.000	17.000
	D2	10	2.400	4.169	0.000	14.000	14.000
	E2	7	2.857	3.848	0.000	9.000	9.000
	F2	9	1.667	1.323	1.000	5.000	4.000
	G2	10	2.400	4.061	0.000	10.000	10.000
	H2	10	2.400	1.265	1.000	5.000	4.000
	I2	8	3.750	7.421	0.000	22.000	22.000
	J2	11	2.000	3.521	0.000	12.000	12.000
Surface Water	Channel	11	32.182	28.586	1.000	85.000	84.000
	River	9	9.556	6.654	0.000	21.000	21.000

Site Type						
Upper Wells	110	4.636	6.441	0.000	49.000	49.000
Lower Wells	100	2.925	4.072	0.000	22.000	22.000
Surface Water	20	22.000	24.127	0.000	85.000	85.000
Total	230	5.402	10.111	0.000	85.000	85.000

TKN (mg/l)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	8	1.375	1.026	0.000	3.200	3.200
	B1	7	28.914	57.906	2.900	160.000	157.100
	C1	6	425.667	249.785	190.000	790.000	600.000
	D1	7	3.771	3.333	0.100	9.500	9.400
	E1	7	10.557	12.516	1.700	34.000	32.300
	F1	8	24.075	16.135	5.000	48.000	43.000
	G1	5	132.400	66.860	49.000	190.000	141.000
	H1	7	0.629	0.621	0.000	1.900	1.900
	I1	7	0.371	0.687	0.000	1.900	1.900
	J1	7	0.143	0.294	0.000	0.800	0.800
Lower Wells	A2	8	0.387	0.236	0.000	0.700	0.700
	B2	8	0.862	0.938	0.000	2.800	2.800
	C2	7	57.543	116.329	0.700	320.000	319.300
	D2	7	1.429	1.694	0.000	5.100	5.100
	E2	6	3.583	2.676	1.400	8.800	7.400
	F2	7	6.486	3.113	1.700	9.700	8.000
	G2	5	214.800	121.133	84.000	410.000	326.000
	H2	7	0.800	0.983	0.000	2.900	2.900
	I2	7	0.400	0.523	0.000	1.500	1.500
	J2	7	0.400	0.379	0.000	0.900	0.900
Surface Water	Channel	7	1.400	1.955	0.000	5.600	5.600
	River	6	0.450	0.333	0.000	0.800	0.800
Site Type							
Upper Wells		69	54.062	140.237	0.000	790.000	790.000
Lower Wells		69	22.825	72.593	0.000	410.000	410.000
Surface Water		13	0.962	1.484	0.000	5.600	5.600
Total		151	35.217	107.890	0.000	790.000	790.000

Total Phosphate (mg/l)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	10	0.065	0.036	0.010	0.130	0.120
	B1	10	0.467	0.397	0.170	1.300	1.130
	C1	10	1.683	0.352	1.070	2.400	1.330
	D1	10	0.056	0.065	0.000	0.220	0.220
	E1	10	0.171	0.380	0.020	1.250	1.230
	F1	10	0.078	0.041	0.000	0.150	0.150
	G1	10	0.201	0.185	0.060	0.670	0.610
	H1	10	0.023	0.022	0.000	0.070	0.070
	I1	10	0.012	0.019	0.000	0.060	0.060
	J1	9	0.032	0.047	0.000	0.150	0.150
Lower Wells	A2	9	0.060	0.143	0.000	0.440	0.440
	B2	10	0.136	0.374	0.000	1.200	1.200
	C2	10	0.177	0.201	0.030	0.610	0.580
	D2	10	0.137	0.367	0.000	1.180	1.180
	E2	9	0.272	0.723	0.000	2.200	2.200
	F2	10	0.040	0.064	0.000	0.220	0.220
	G2	10	1.359	0.186	1.100	1.600	0.500
	H2	10	0.025	0.045	0.000	0.150	0.150
	I2	9	0.167	0.463	0.000	1.400	1.400
	J2	10	0.162	0.330	0.030	1.100	1.070
Surface Water	Channel	9	0.048	0.023	0.030	0.090	0.060
	River	7	0.040	0.013	0.030	0.060	0.030
Site Type							
Upper Wells		99	0.281	0.532	0.000	2.400	2.400
Lower Wells		97	0.256	0.503	0.000	2.200	2.200
Surface Water		16	0.044	0.019	0.030	0.090	0.060
Total		212	0.252	0.500	0.000	2.400	2.400

Orthophosphate (mg/l)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	9	0.037	0.019	0.000	0.070	0.070
	B1	9	0.420	0.331	0.120	0.960	0.840
	C1	8	1.716	0.565	1.270	2.670	1.400
	D1	9	0.012	0.016	0.000	0.050	0.050
	E1	9	0.028	0.024	0.000	0.070	0.070
	F1	9	0.042	0.019	0.000	0.060	0.060
	G1	9	0.291	0.241	0.050	0.730	0.680
	H1	9	0.008	0.011	0.000	0.030	0.030
	I1	9	0.000	0.000	0.000	0.000	0.000
	J1	9	0.007	0.007	0.000	0.020	0.020
Lower Wells	A2	8	0.001	0.004	0.000	0.010	0.010
	B2	9	0.000	0.000	0.000	0.000	0.000
	C2	9	0.041	0.028	0.010	0.090	0.080
	D2	9	0.002	0.004	0.000	0.010	0.010
	E2	9	0.000	0.000	0.000	0.000	0.000
	F2	9	0.004	0.007	0.000	0.020	0.020
	G2	8	1.231	0.109	1.100	1.400	0.300
	H2	9	0.001	0.003	0.000	0.010	0.010
	I2	9	0.004	0.007	0.000	0.020	0.020
	J2	9	0.053	0.029	0.020	0.100	0.080
Surface Water	Channel	9	0.024	0.018	0.000	0.050	0.050
	River	8	0.011	0.011	0.000	0.030	0.030
Site Type							
Upper Wells		89	0.240	0.527	0.000	2.670	2.670
Lower Wells		88	0.123	0.355	0.000	1.400	1.400
Surface Water		17	0.018	0.016	0.000	0.050	0.050
Total		194	0.167	0.434	0.000	2.670	2.670

Sulfate (mg/l)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	10	26.350	28.893	0.000	89.000	89.000
	B1	11	11.864	12.748	0.000	45.000	45.000
	C1	11	12.091	2.879	6.000	15.000	9.000
	D1	10	63.000	36.092	13.000	120.000	107.000
	E1	10	6.070	7.870	0.000	27.000	27.000
	F1	11	4.836	3.841	0.000	10.000	10.000
	G1	10	5.060	3.969	0.000	13.000	13.000
	H1	10	6.670	2.756	2.000	10.000	8.000
	I1	10	21.400	8.099	6.000	28.000	22.000
	J1	10	14.400	6.041	0.000	21.000	21.000
Lower Wells	A2	10	46.600	58.127	0.000	190.000	190.000
	B2	11	9.818	7.900	0.000	22.000	22.000
	C2	11	4.927	3.384	0.000	11.000	11.000
	D2	10	2.010	2.150	0.000	5.000	5.000
	E2	9	1.500	2.264	0.000	6.000	6.000
	F2	11	1.027	1.774	0.000	5.000	5.000
	G2	10	9.300	1.168	7.000	11.000	4.000
	H2	10	4.790	1.880	1.000	8.000	7.000
	I2	8	10.062	11.188	3.900	31.000	27.100
	J2	10	44.550	110.905	6.000	360.000	354.000
Surface Water	Channel	9	571.556	463.661	94.000	1540.000	1446.000
	River	8	322.125	237.322	37.000	700.000	663.000
Site Type							
Upper Wells		103	16.953	22.347	0.000	120.000	120.000
Lower Wells		100	13.400	41.413	0.000	360.000	360.000
Surface Water		17	454.176	385.487	37.000	1540.000	1503.000
Total		220	49.124	160.218	0.000	1540.000	1540.000

Chloride (mg/l)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	8	725.375	392.886	226.000	1330.000	1104.000
	B1	8	799.750	824.117	191.000	2740.000	2549.000
	C1	8	1393.750	366.253	1090.000	2270.000	1180.000
	D1	8	716.000	349.007	162.000	1030.000	868.000
	E1	8	534.000	274.306	333.000	1150.000	817.000
	F1	8	523.125	139.935	365.000	800.000	435.000
	G1	8	625.500	239.240	355.000	1040.000	685.000
	H1	8	53.875	29.396	34.000	110.000	76.000
	I1	8	27.375	22.947	7.000	82.000	75.000
	J1	8	30.625	5.263	25.000	40.000	15.000
Lower Wells	A2	7	1127.429	630.978	385.000	2223.000	1838.000
	B2	8	921.000	304.566	548.000	1500.000	952.000
	C2	8	384.875	358.702	70.000	1140.000	1070.000
	D2	8	555.625	142.961	429.000	880.000	451.000
	E2	7	846.429	204.462	666.000	1230.000	564.000
	F2	8	280.375	131.630	71.000	460.000	389.000
	G2	8	1239.125	309.165	1020.000	1950.000	930.000
	H2	8	63.125	20.622	44.000	100.000	56.000
	I2	7	14.714	9.013	7.000	30.000	23.000
	J2	8	15.875	9.523	3.000	30.000	27.000
Surface Water	Channel	8	5507.500	2056.685	3296.000	8850.000	5554.000
	River	6	5794.667	2433.743	3050.000	8650.000	5600.000

Site Type	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	80	542.938	524.382	7.000	2740.000	2733.000
Lower Wells	77	540.260	512.393	3.000	2223.000	2220.000
Surface Water	14	5630.571	2139.517	3050.000	8850.000	5800.000
Total	171	958.263	1597.912	3.000	8850.000	8847.000

Sodium (mg/l)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	12	668.333	214.681	370.000	1020.000	650.000
	B1	12	878.333	782.790	180.000	2180.000	2000.000
	C1	12	858.333	95.330	690.000	1010.000	320.000
	D1	12	539.167	263.558	170.000	1030.000	860.000
	E1	12	441.667	101.429	280.000	610.000	330.000
	F1	12	468.333	103.294	310.000	650.000	340.000
	G1	12	481.667	95.235	350.000	680.000	330.000
	H1	11	44.364	8.310	31.000	53.000	22.000
	I1	12	29.000	10.988	18.000	51.000	33.000
	J1	12	37.250	13.465	25.000	58.000	33.000
Lower Wells	A2	11	746.364	216.161	500.000	1240.000	740.000
	B2	12	659.500	210.003	64.000	850.000	786.000
	C2	12	430.000	231.831	180.000	860.000	680.000
	D2	12	512.500	119.630	360.000	650.000	290.000
	E2	11	660.000	116.017	380.000	790.000	410.000
	F2	12	340.833	81.626	230.000	460.000	230.000
	G2	12	996.667	297.454	770.000	1900.000	1130.000
	H2	12	57.333	14.240	28.000	76.000	48.000
	I2	11	25.636	8.488	14.000	36.000	22.000
	J2	12	27.167	9.233	17.000	39.000	22.000
Surface Water	Channel	8	4893.750	1075.213	3500.000	6500.000	3000.000
	River	8	4837.500	945.013	3800.000	6800.000	3000.000
Site Type							
Upper Wells		119	448.008	404.563	18.000	2180.000	2162.000
Lower Wells		117	444.786	354.992	14.000	1900.000	1886.000
Surface Water		16	4865.625	978.318	3500.000	6800.000	3300.000
Total		252	726.996	1165.439	14.000	6800.000	6786.000

Potassium (mg/l)

Site Type	Site	Num. Sapl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	12	106.583	174.585	38.000	660.000	622.000
	B1	12	433.417	648.169	33.000	1520.000	1487.000
	C1	12	1335.000	168.064	1030.000	1530.000	500.000
	D1	12	30.417	13.132	7.000	45.000	38.000
	E1	12	98.417	55.556	29.000	200.000	171.000
	F1	12	66.500	17.344	44.000	92.000	48.000
	G1	12	454.167	42.525	420.000	540.000	120.000
	H1	11	1.727	0.467	1.000	2.000	1.000
	I1	12	2.000	0.000	2.000	2.000	0.000
	J1	12	2.167	0.389	2.000	3.000	1.000
Lower Wells	A2	11	38.727	23.057	15.000	80.000	65.000
	B2	12	57.500	61.098	14.000	150.000	136.000
	C2	12	189.250	242.707	43.000	730.000	687.000
	D2	12	15.333	2.605	11.000	18.000	7.000
	E2	11	30.091	3.646	26.000	40.000	14.000
	F2	12	17.750	19.415	3.000	76.000	73.000
	G2	12	928.333	155.904	540.000	1120.000	580.000
	H2	12	4.500	1.168	3.000	6.000	3.000
	I2	11	4.545	7.461	2.000	27.000	25.000
	J2	12	2.333	0.888	2.000	5.000	3.000
Surface Water	Channel	11	127.182	62.032	45.000	260.000	215.000
	River	9	122.556	50.814	55.000	190.000	135.000
Site Type							
Upper Wells		119	255.151	451.102	1.000	1530.000	1529.000
Lower Wells		117	131.513	290.478	2.000	1120.000	1118.000
Surface Water		20	125.100	55.839	45.000	260.000	215.000
Total		256	188.484	369.675	1.000	1530.000	1529.000

Calcium (mg/l)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	12	89.250	25.140	42.000	120.000	78.000
	B1	12	103.167	38.221	43.000	150.000	107.000
	C1	12	85.000	9.573	71.000	100.000	29.000
	D1	12	36.750	18.346	12.000	60.000	48.000
	E1	12	44.500	17.661	23.000	78.000	55.000
	F1	12	58.083	11.958	34.000	77.000	43.000
	G1	12	70.583	10.004	51.000	80.000	29.000
	H1	11	11.364	3.695	6.000	17.000	11.000
	I1	12	3.667	0.492	3.000	4.000	1.000
	J1	12	31.083	3.450	27.000	38.000	11.000
Lower Wells	A2	11	100.636	24.861	50.000	126.000	76.000
	B2	12	131.833	17.383	100.000	150.000	50.000
	C2	12	86.000	21.247	60.000	144.000	84.000
	D2	12	118.667	16.675	96.000	150.000	54.000
	E2	11	208.182	27.863	160.000	260.000	100.000
	F2	12	149.667	63.917	90.000	331.000	241.000
	G2	12	119.583	29.268	95.000	210.000	115.000
	H2	12	72.167	18.775	23.000	89.000	66.000
	I2	11	19.455	26.760	9.000	100.000	91.000
	J2	12	78.083	11.066	62.000	100.000	38.000
Surface Water	Channel	11	122.091	50.830	50.000	210.000	160.000
	River	9	119.556	40.887	60.000	170.000	110.000

Site Type	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	119	53.697	36.173	3.000	150.000	147.000
Lower Wells	117	108.402	55.074	9.000	331.000	322.000
Surface Water	20	120.950	45.447	50.000	210.000	160.000
Total	256	83.953	54.295	3.000	331.000	328.000

Magnesium (mg/l)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	12	49.417	24.511	17.000	90.000	73.000
	B1	12	58.833	49.849	17.000	140.000	123.000
	C1	12	108.333	11.934	90.000	120.000	30.000
	D1	12	53.833	29.890	15.000	100.000	85.000
	E1	12	35.917	18.628	16.000	88.000	72.000
	F1	12	63.750	14.417	34.000	91.000	57.000
	G1	12	69.917	7.229	60.000	81.000	21.000
	H1	11	3.727	0.647	3.000	5.000	2.000
	I1	12	6.000	0.953	5.000	8.000	3.000
	J1	12	3.167	1.030	2.000	5.000	3.000
Lower Wells	A2	11	63.091	32.414	24.000	140.000	116.000
	B2	12	40.167	3.689	36.000	49.000	13.000
	C2	12	30.333	35.737	9.000	110.000	101.000
	D2	12	41.500	8.426	27.000	64.000	37.000
	E2	11	80.545	9.081	64.000	90.000	26.000
	F2	12	44.333	63.461	13.000	240.000	227.000
	G2	12	150.833	37.040	110.000	260.000	150.000
	H2	12	4.833	0.389	4.000	5.000	1.000
	I2	11	10.909	22.598	3.000	79.000	76.000
	J2	12	4.167	1.899	3.000	10.000	7.000
Surface Water	Channel	11	338.182	145.177	120.000	600.000	480.000
	River	8	331.250	133.677	140.000	480.000	340.000

Site Type	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	119	45.639	38.427	2.000	140.000	138.000
Lower Wells	117	46.957	50.640	3.000	260.000	257.000
Surface Water	19	335.263	136.641	120.000	600.000	480.000
Total	255	67.824	94.666	2.000	600.000	598.000

Iron (mg/l)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	12	6.250	2.350	3.300	11.000	7.700
	B1	12	7.617	5.210	1.100	19.000	17.900
	C1	12	2.767	1.774	0.300	6.500	6.200
	D1	12	16.167	8.164	2.400	31.000	28.600
	E1	12	7.917	7.189	1.300	22.000	20.700
	F1	12	10.983	23.709	1.600	86.000	84.400
	G1	12	8.333	5.004	1.200	17.000	15.800
	H1	11	3.082	2.021	1.800	9.000	7.200
	I1	12	1.608	2.993	0.200	11.000	10.800
	J1	12	2.625	4.011	0.100	15.000	14.900
Lower Wells	A2	11	14.118	41.758	0.400	140.000	139.600
	B2	12	3.067	8.494	0.200	30.000	29.800
	C2	12	1.742	2.445	0.300	7.400	7.100
	D2	12	10.458	34.500	0.000	120.000	120.000
	E2	11	11.645	5.681	0.200	20.000	19.800
	F2	12	53.142	181.664	0.100	630.000	629.900
	G2	12	23.258	74.562	0.800	260.000	259.200
	H2	12	1.275	3.694	0.100	13.000	12.900
	I2	11	46.836	137.158	0.000	460.000	460.000
	J2	12	0.842	2.324	0.000	8.200	8.200
Surface Water	Channel	11	0.482	0.271	0.200	1.000	0.800
	River	9	0.456	0.246	0.200	0.900	0.700

Site Type						
Upper Wells	119	6.766	9.508	0.100	86.000	85.900
Lower Wells	117	16.444	76.692	0.000	630.000	630.000
Surface Water	20	0.470	0.254	0.200	1.000	0.800
Total	256	10.697	52.421	0.000	630.000	630.000

Manganese (mg/l)

Site Type	Site	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	A1	12	0.533	0.261	0.200	1.100	0.900
	B1	12	0.458	0.525	0.200	2.100	1.900
	C1	12	0.392	0.067	0.300	0.500	0.200
	D1	12	0.125	0.062	0.100	0.300	0.200
	E1	12	0.158	0.067	0.100	0.300	0.200
	F1	12	0.233	0.089	0.200	0.500	0.300
	G1	12	0.433	0.107	0.300	0.700	0.400
	H1	11	0.036	0.050	0.000	0.100	0.100
	I1	12	0.083	0.039	0.000	0.100	0.100
	J1	12	0.192	0.029	0.100	0.200	0.100
Lower Wells	A2	11	0.236	0.136	0.000	0.500	0.500
	B2	12	0.267	0.078	0.200	0.400	0.200
	C2	12	0.067	0.098	0.000	0.300	0.300
	D2	12	0.317	0.255	0.100	1.100	1.000
	E2	11	0.545	0.104	0.300	0.700	0.400
	F2	12	1.025	3.142	0.000	11.000	11.000
	G2	12	0.492	0.696	0.200	2.700	2.500
	H2	12	0.017	0.039	0.000	0.100	0.100
	I2	11	0.627	1.295	0.000	4.500	4.500
	J2	12	0.175	0.097	0.000	0.400	0.400
Surface Water	Channel	11	0.091	0.083	0.000	0.200	0.200
	River	9	0.067	0.050	0.000	0.100	0.100

Site Type	Num. Smpl	Mean	Std. Dev.	Min	Max	Range
Upper Wells	119	0.266	0.251	0.000	2.100	2.100
Lower Wells	117	0.374	1.106	0.000	11.000	11.000
Surface Water	20	0.080	0.070	0.000	0.200	0.200
Total	256	0.301	0.770	0.000	11.000	11.000